Co-siting solutions

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In a world with several mobile system standards and a shortage of attractive sites, operators must sometimes share sites. Ericsson supplies system equipment for all major mobile system standards and has extensive know-how and experience of providing co-siting solutions.

The authors discuss the most important characteristics of equipment that must share radio base station sites.

Introduction

In the early 1990s, when GSM was first released, several operators asked Ericsson if they could share the sites of their first-generation analog mobile systems with new second-generation systems. In response to these queries, Ericsson developed custom kits that allowed co-siting between

- GSM 900 and TACS (and E-TACS) at 900 MHz; and
- GSM 900 and NMT 900.

A few years later, many GSM 900 operators received additional spectrum for the 1800 MHz band, which necessitated co-siting solutions for GSM 900 and 1800. Ericsson thus developed radio base station (RBS) cabinets that contained both frequency bands simultaneously. At the same time, solutions multiplied for co-siting GSM 900 sites with GSM 1800 equipment.

At present, operators in many countries are rolling out WCDMA, creating demand for co-siting solutions for GSM and WCDMA. Operators also want to co-site GSM with many TDMA sites, especially in North America. Likewise, many operators in North America are poised to roll out WCDMA on the 1900 MHz band.

In summary, there is great demand for co-siting solutions. And since Ericsson supports all major mobile system standards, it can provide every conceivable co-siting solution. Indeed, Ericsson designed its radio base stations with co-siting in mind.

The term co-siting is often used to mean different things. At Ericsson, and in the context of this article, it is used to signify the sharing of equipment between different systems at a given site, for example, the antenna system, power and battery backup system, transmission, cooling, and shelters. Co-siting is not synonymous with co-location and co-existence. Co-location indicates that the same premises are used but without sharing vital equipment. Similarly, co-existence means that two or more radio frequency (RF) systems are operating in the same area—for instance, when antennas from two operators are located on the same or nearby rooftops.

This article solely discusses the co-siting of antenna systems for TDMA and GSM, and GSM and WCDMA. It does not handle the co-siting of power, transmission, cooling and shelter.

Why co-siting?

Many operators who are in the process of expanding or rolling out a new network find it difficult to obtain new sites for radio base stations. Likewise, due to restrictions from authorities, zoning regulations, or concerns regarding RF exposure, it is often difficult to add antennas to existing sites. Co-siting solutions, however, enable operators to reuse existing equipment. In many countries, for example, operators rolling out WCDMA networks expect to deploy up to 80% of the new system alongside existing GSM equipment.

When planning rollout, operators need to consider the rate at which subscribers will convert from, say, GSM to WCDMA, so that they can optimize capacity. This transition could be dependent, for example, on growth in traffic from video applications in

BOX A, TERMS AND ABBREVIATIONS

3GPP	Third-generation Partnership Project	OMT	Operation and maintenance terminal
ARP	Antenna reference point	OVP	Over-voltage protection
ASC	Antenna system controller	PCM	Pulse code modulation
ASU	Antenna sharing unit	RBS	Radio base station
BSS	Base station subsystem	RBS 882	Ericsson TDMA radio base station for 850 MHz
CDU-F	Combiner and distribution module, filter version	RBS 884	Ericsson TDMA radio base station for 850 and 1900 MHz
CDU-G	Combiner and distribution module, hybrid version	RBS 2000	Ericsson's family of GSM RBSs
CXU	Configuration switch unit	RBS 2x02	RBS2102 and RBS2202
ddTMA	Dual-duplex TMA	RBS 3000	Ericsson family of WCDMA RBSs
DF	Distribution frame	RF	Radio frequency
dTRU	Double transceiver unit	RX	Receiver
E1	2 Mbit/s PCM link	RXBP	Receiver band-pass filter
EDGE	Enhanced data rates for global evolution	T1	1.5 Mbit/s PCM link
ESB	External synchronization bus (for RBS 2000 synchronization feature, TG sync)	TACS	Total access communication s ystem (first-generation analog mobile system, frequency allocation 900 MHz)
ETSI	European Telecommunication Standardization Institute	TDMA	Time-division multiple access (second-generation analog mobile system; previously called AMPS. TDMA is available at 850 and 1900 MHz)
GPRS	General packet radio service	TMA	Tower-mounted amplifier
GSM	Global system for mobile communication (GSM is available at 800, 900, 1800 and 1900 MHz)	TRU	Ericsson transceiver unit
IM	Intermodulation	TRX	Transceiver
LMU	Location measuring unit	TX	Transmitter
NMT	Nordic mobile telephone	VSWR	Voltage standing-wave ratio

WCDMA networks. Considerations of this kind influence how operators plan for equipment at RBS sites. Note: Co-siting is always a trade-off between saving antenna system resources and maintaining optimum operational performance.

Ericsson co-siting solutions

Basic techniques

In general, two basic techniques are used in RF co-siting: filter combiners and hybrid combiners.

A filter combiner has two or more filter branches connected to a common port. Each filter branch is designed to have a defined frequency range that enables signals from each branch to be combined on the common port without signals from one branch leaking into another branch.

The filter combiner also allows a combined signal that has been inserted into the common port to be separated into its components on the separate branches. The general characteristics of filter combiners are

- low loss; and
- excellent isolation between branches. To maintain isolation, filter combiners require separation between the frequency ranges of the different branches.

Filter combiners can be used for combining and separating signals.

A hybrid combiner has two branches and four ports that cover a certain, often fairly wide, frequency range. It is designed so that two signals input into two of the ports are combined and output on the other two ports. Since the hybrid combiner does not employ active amplification, half of each input signal is channeled to each output port. If only one combined signal is required, the other output port is connected to ground via a load resister and half the input power is converted to heat.

If several output signals are required—for example, in an indoor distributed antenna system—both branches can be used without wasting power. Some general characteristics of a hybrid combiner are

- significant loss if used to combine two signals into one input; and
- less isolation (compared to filter combiners) between inputs.

When a hybrid combiner is used, the signals to be combined do not have to be separated in frequency.

Antenna-sharing unit

The antenna-sharing unit (ASU), which is an optional unit integrated into the RBS 2106 and RBS 2206, uses hybrid combiner techniques to share the receiver (RX) signal from the GSM base station to another RBS (Figure 1). The ASU is evidence that Ericsson was early to recognize the potential of co-siting.

Filters and combiners

Filter combiners for co-siting purposes include duplex and diplex filters (Figure 1). Duplex filters combine the transmit (TX) and receive signals of a specific frequency band into a common signal. The filters are usually built into the RBS, but can also be used as an external component in the antenna system.

Diplex filters further combine combined TX/RX signals from separate frequency bands into a common signal—for example, the TX/RX signals of GSM 900 and 1800 can be combined on a shared antenna feeder cable and split into separate signals at the top of the antenna mast.

TDMA-GSM co-siting

TDMA systems on 850 and 1900 MHz have been deployed quite extensively in North America. GSM 800 and GSM 1900 are also available in North America. Therefore, operators have requested co-siting solutions for these systems.

When introducing GSM 800 and 900, many TDMA operators want to minimize tower work and the need for additional antenna system equipment. The two main types of RF co-siting solutions are

- TDMA-GSM single-band—for example, TDMA 1900 co-sited with GSM 1900; and
- TDMA-GSM dual-band—for example, TDMA 1900 co-sited with GSM 800.

TDMA-GSM single-band antenna-sharing

Ericsson's solution shares RX antennas but maintains separate TX antennas for each system. For optimum performance and minimum noise, the GSM radio base station serves as master and the TDMA radio base station as slave. The physical antennas for picking up RX signals are thus connected to the GSM radio base station and forwarded to the TDMA radio base station using the antenna-sharing unit built into the GSM radio base station. The TX

TABLE 1, MOBILE SYSTEM DEPLOYMENT

Mobile system	Geographic region
GSM 800	North and South America
GSM 900	Europe, Asia, China, Australia
GSM 1800	Europe, Asia, China,Australia
GSM 1900	North and South America
TDMA 850	North and South America
TDMA 1900	North and South America
WCDMA 1900	North America
WCDMA 2100	Europe, Asia, Australia
CDMA 1900	North and South America, Australia, China

Figure 1
Top: The ASU delivers a high-quality RX signal to the receiving RBS. Center: A double duplex filter is used for GSM 1800 and GSM 1900. Bottom: A diplex filter is used for combining GSM 900 and 1800 or GSM 800 and 1900.

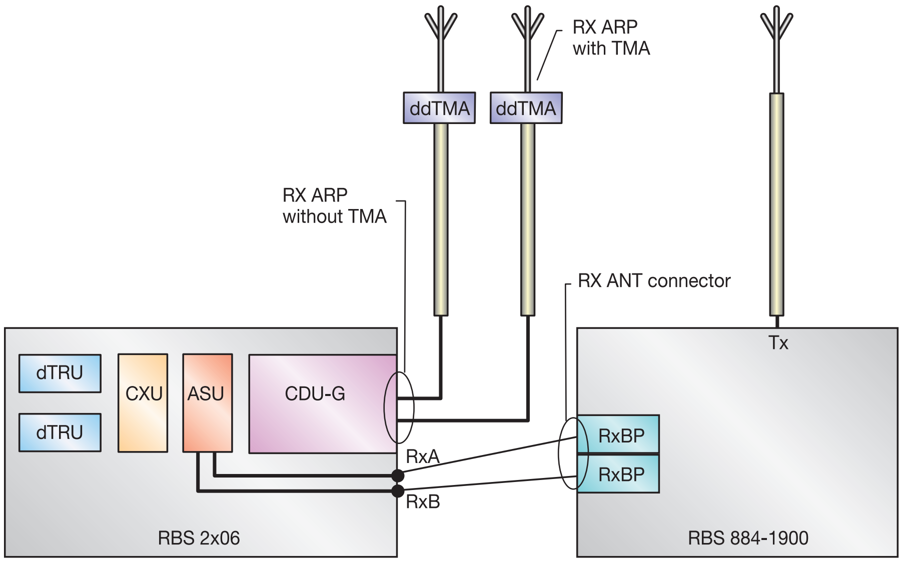


Figure2
Single-band co-siting between GSM 1900 and TDMA 1900.

antennas remain connected to separate RBSs.

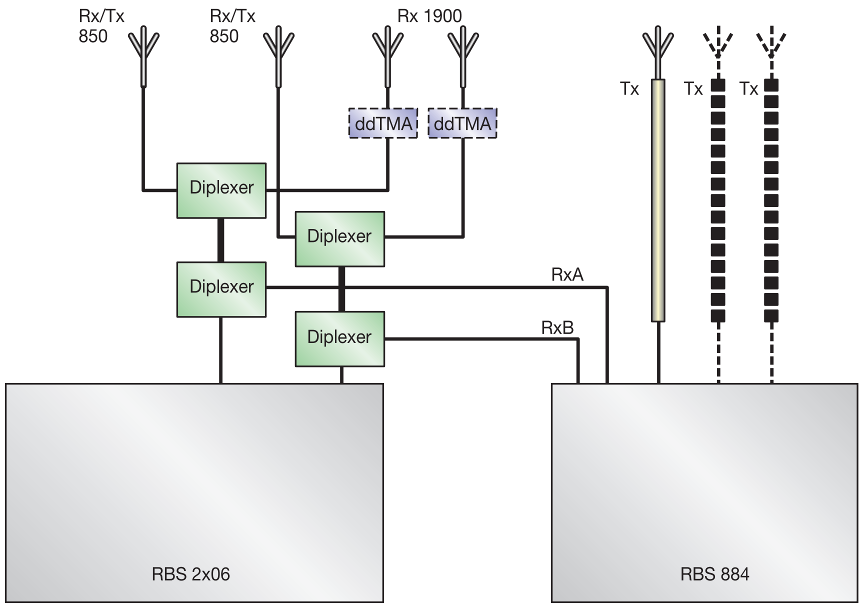
Figure 2 shows one sector. The loss of an RX antenna-sharing cable is a critical parameter. Therefore, each combination of GSM and TDMA radio base stations requires an RX antenna-sharing cable kit that has been optimized for that specific combination.

The lower noise figure in the GSM receiver path yields performance advantages when the GSM radio base station serves as master.

The RX antenna feeder-sharing option solely applies to a slave RBS with non-duplexed RX and TX paths. In practice, this means that existing TDMA RX feeders are moved to the TX/RX ports of a co-sited GSM radio base station. The existing TDMA tower-mounted amplifiers (TMA) must be replaced with GSM dual-duplex TMAs. For optimum performance, the operator should also consider replacing the antenna and feeders.

Since TDMA radio base stations typically employ space diversity, operators can reduce the overall number of antennas by replacing two vertical polarized TDMA RX antennas with one GSM TX/RX cross-polarized antenna.

Figure 3
Dual-band co-siting solution that shares a feeder between GSM 800 and TDMA 1900.



TDMA-GSM dual-band feeder-sharing solutions

Some restrictions might apply to antennas or feeders when GSM 800 is introduced at an existing TDMA 1900 site, or GSM 1900 at an existing TDMA 850 site.

Figure 3 shows one sector of a GSM 800 system co-sited with a TDMA 1900 system. Diplexers, which combine and split the signals of the two mobile systems operating in

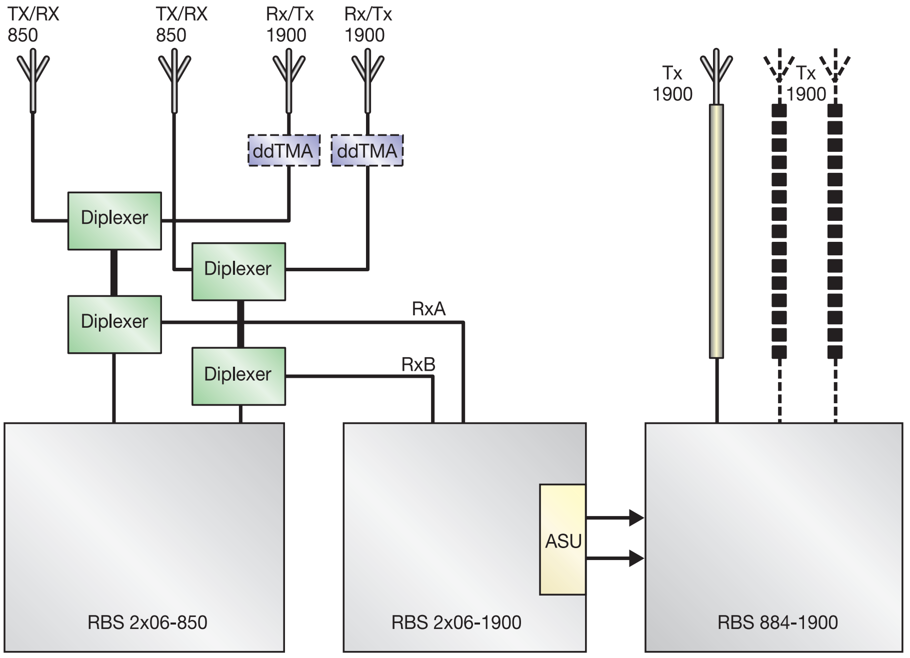


Figure 4
Dual-band co-siting solution that shares feeders between GSM 800, GSM 1900 and TDMA 1900.

different frequency bands, facilitate feeder-sharing. Excellent isolation guarantees system integrity of co-sited systems.

Figure 4 shows one sector of a co-sited system consisting of GSM 800, GSM 1900 and TDMA 1900.

Minimizing the number of antennas

Many TDMA sites have vertical polarized antennas. When co-siting systems, operators can replace two vertical polarized TDMA RX antennas with

- a single cross-polarized antenna for TDMA RX signals; and
- a single cross-polarized antenna for GSM.

Likewise, as an option, they might deploy cross-polarized double antennas with four antenna functions (two low-band and two high-band) in the same radome.

Operators introducing GSM alongside TDMA, but who cannot or may not install additional feeders, can instead share feeders provided they install diplex filters at the radio base stations and in the tower. A diplex filter has three ports (high-band, low-band, shared). Ordinarily, four diplex filters are required per sector (two at the RBS and two in the tower). Jumper cables for interfacing the diplex filters to radio base stations, antennas and feeder cables (and in some cases, TMAs) are also required. Since the layout will vary from site to site, Ericsson offers a range of useful accessories.

Where RF performance is concerned, separate feeders are always preferred. Feeder-sharing solutions have greater loss and intermodulation, and require higher voltage standing-wave ratio (VSWR) limits. Diplex filters and extra jumper cables introduce additional loss and reduce the link budget by approximately 1 dB.

TMA signaling for one system can be handled via feeder-sharing. However, the use of TMAs on both bands requires separate DC cables to the tower, which minimizes the benefits of feeder-sharing. Therefore, feeder-sharing is not recommended when both systems use TMAs.

The preferred feeder-sharing solution solely shares feeders for GSM signals and TDMA RX signals. Operators who implement feeder-sharing for TDMA TX or TDMA TX/RX signals, must ensure that the equipment can withstand the power levels. Moreover, intermodulation might become an issue due to the number of connections and extra equipment.

GSM-WCDMA co-siting

Third-generation mobile systems are being rolled out in many countries. In Europe, Asia and Australia, this means that there is a need for co-siting GSM 900, GSM 1800 and WCDMA 2100. In North America, co-siting solutions are required for GSM 800,

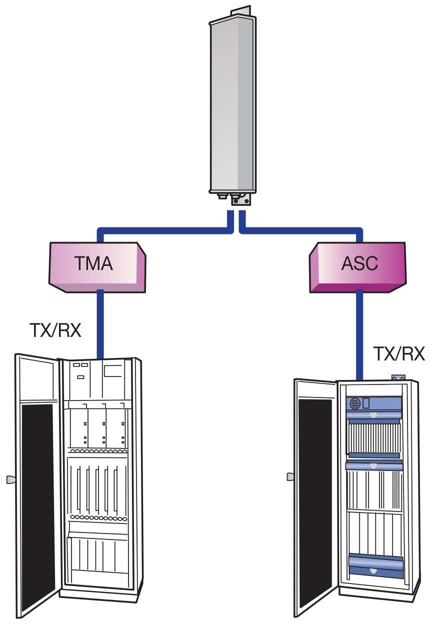


Figure 5
Antenna-sharing between a GSM system and a WCDMA system.

GSM 1900 and WCDMA 2100. In the text that follows, we take a closer look at co-siting solutions for
- GSM 900 and WCDMA 2100; and
- GSM 1800 and WCDMA 2100.

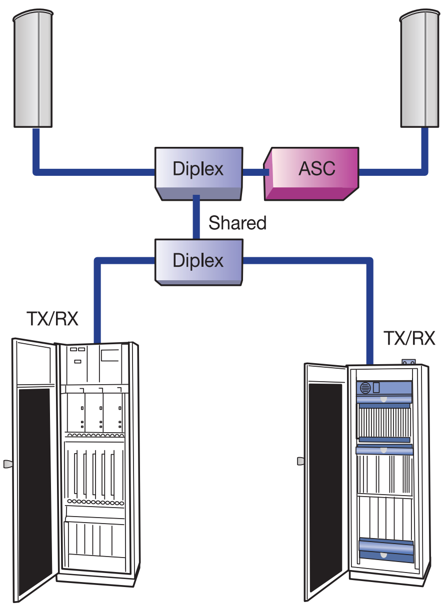


Figure 6
Feeder-sharing between a GSM system and a WCDMA system.

Antenna-sharing

Depending on the requirements, there are several ways of co-siting GSM and WCDMA antenna systems. The simplest method is to share antennas, replacing existing antennas with cross-polarized double antennas (Figure 5). This solution affects cell planning, since the antenna direction is the same for each system. Antenna isolation between the systems must be at least 30 dB.

The solution described here applies to GSM 900 and GSM 1800 when co-sited with WCDMA 2100. Sites with GSM 900, GSM 1800 and WCDMA 2100 can share triple-band cross-polarized antennas. Antenna-sharing is an ideal solution for operators who need to minimize the visual impact of the site.

Feeder-sharing

Diplexers are used to share feeders between two systems, for example, GSM 900 and GSM 1800 when co-sited with WCDMA 2100. The diplexers have three contacts: one for GSM (either 900 or 1800), one for WCDMA, and one for the shared feeder. Two diplexers are used for each feeder in the sector: one close to the base station, and another close to the antenna (Figure 6).

The use of diplexers results in a slight loss of output power from the base stations. An insertion loss between 0.2 and 0.7 dB in each diplexer for each frequency band is foreseen.

Feeder-sharing and antenna-sharing can be used in combination. In this case, the diplexer closest to the antenna is either an external device or built into the antenna.

The combination can also be applied when co-siting GSM 900, GSM 1800 and WCDMA 2100. However, to combine signals from three systems, triplexers are used instead of diplexers.

Feeder-sharing is especially suitable when the distance between the base station and the antenna is great and cost is more important than radio performance. This technique is also used when building or tower restrictions keep operators from installing more feeders at a site.

Performance considerations

General aspects

Radio performance can be affected when two different systems are co-sited. Therefore, to prevent problems that might affect performance, the job must be done correctly. Notwithstanding, co-siting is always an option.

Guard band and carrier separation

A guard band is the unused frequency band between two mobile systems. Figure 7 describes the guard band and carrier separation.

Isolation between systems

System isolation is achieved by the attenuation between the transmitter reference point in the interfering system and the receiver reference point. In Figure 8, RBS *X* is disturbing RBS *Y*. The isolation between the reference points is calculated as follows:

Feeder loss 1 – Antenna gain 1 + Propagation loss – Antenna gain 2 + Feeder loss 2 + Extra filter loss

Isolation is thus the total path loss due to feeder losses, propagation and attenuation in any extra filters or other devices. For distances greater than 10 m, the propagation loss can be approximated by free-space propagation. For short antenna separations, the value *(– Antenna gain 1 + Propagation loss – Antenna gain 2)* can be approximated with measured coupling loss of typical antennas.

Spurious emission and harmonics

The term spurious emission is frequently used to mean all unwanted emission from a transmitter. This could be

- the products of intermodulation (IM) caused by different frequencies in the transmitter (actual spurious emission);
- intermodulation caused by carrier frequencies;
- harmonics, which are peaks at double carrier frequencies; and
- noise.

Each of these sources can cause co-channel interference in a nearby receiver. Although high levels of spurious emissions have been documented, the occurrence is rare, and the probability that system channels will be affected is low.

Transmitter noise

Spurious emissions are occasional peaks outside the carrier. Noise, on the other hand, is the lowest level of continuous wideband emissions. As with other components of spurious emissions, transmitter noise cannot be minimized through frequency planning or ignored due to improbability. Instead, extra transmitter filters are required on the interfering system.

Intermodulation products

The products of intermodulation are created when two or more frequencies mix in nonlinear devices in the transmit or receive path. Products of order *n* are the sums and differences, in *n* terms of the original frequencies. The strength of intermodulation products declines with higher orders (Figure 9. Note how the product broadens as the order increases). If one term is weaker than the others, the intermodulation product decreases considerably.

The products of transmitter (TX) intermodulation are created at the transmitting RBS through the mixing of carriers in the same power amplifier, combiner, duplex filter, connectors, or antenna, and can lead to co-channel interference, which requires considerable isolation between systems or the addition of filters to the interfering system.

Receiver (RX) intermodulation is created in the receiver amplifiers. In the sense of co-existence, the main difference between TX and RX intermodulation is that the magnitude of co-channel interference from TX intermodulation is more predictable than interference from RX intermodulation. TX intermodulation is about 60 to 70 dBc (dB below the carrier), whereas the strength of RX IM3 and IM5 rises 3 to 5 times more quickly (in dB) than the received carriers that create interference modulation. Since the strength of RX intermodulation products increases rapidly with the power of strong received carriers, RX intermodulation is often associated with an RX intermodulation rejection level. Carriers above the intermodulation rejection level might constitute severe interference, whereas carriers below the intermodulation rejection level are harmless.

Receiver blocking

The receiver blocking level is the maximum level of a non-adjacent or co-channel interferer that can be received at the same time as a weak input signal without degrading receiver performance. Ordinarily, it is defined as a function of frequency separation between the strong and weak signals.

In-band blocking is for strong signals within the receiver RF band. Out-of-band blocking refers to strong signals outside the receiver RF band, where the RF band filter improves rejection. The cause of blocking can be harmonics and noise.

Ericsson and non-Ericsson equipment

Ericsson applies two broad categories to co-siting:

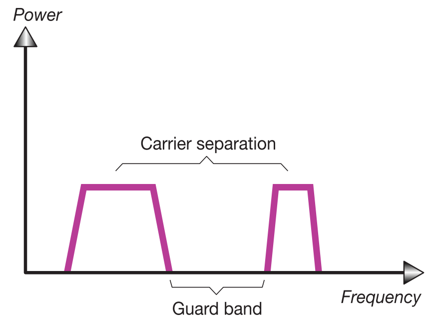
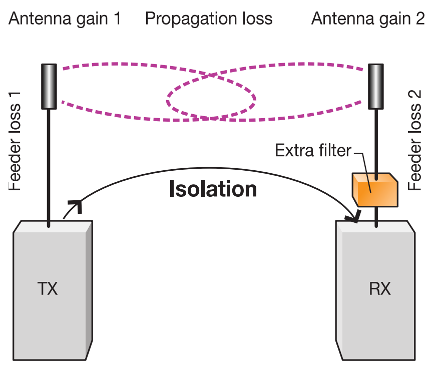


Figure 7
Illustration describing a guard band and carrier separation.

Figure 8
Isolation between systems. Isolation is the total path loss due to feeder losses, propagation and attenuation in any extra filters or devices.



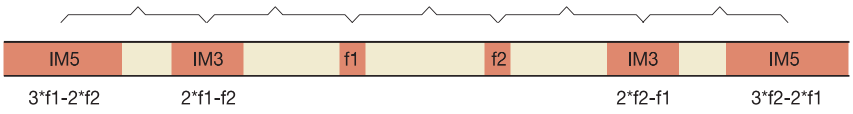


Figure 9
Example of odd-order intermodulation (IM) products of two frequencies, *f1* and *f2*.

- co-siting of systems made up entirely of Ericsson equipment; and
- co-siting of an Ericsson system and a system from another vendor.

TDMA and GSM

When TDMA and GSM systems are to be combined on the same frequency band, the greatest potential problem is interference caused by the near-far problem. This can usually be avoided by means of a guard band of 200 kHz. In addition, all base station antennas should meet minimum isolation requirements of 30 dB, which is standard for most antennas on the market.

When two systems are to be combined on different frequency bands (800 and 1900 MHz), the standard 30 dB cabinet-to-cabinet isolation has been verified to eliminate interference. Experience has shown that this also applies when other vendor equipment is co-sited with equipment from Ericsson.

GSM and WCDMA

The effect of blocking and spurious emissions is dependent on co-siting methods and antenna isolation. A minimum of 30 dB antenna isolation is required between WCDMA and GSM antenna systems. When feeders are shared, the first diplexer closest to the base station must have at least 50 dB isolation between frequency bands.

Ericsson's WCDMA (RBS 3000) and GSM (RBS 2000 and RBS 200) equipment exceeds the ETSI requirements. Therefore, no specific measures must be taken when co-siting equipment from Ericsson.

However, some problems might be encountered when co-siting Ericsson equipment with generic GSM equipment from other vendors, since there are no stringent specifications in GSM 05.05 for the WCDMA RX band (1920-1980 MHz). This shortcoming affects all vendors.

In some cases, operators might need to include an uplink rejection filter in the TX branch of the GSM base station. Ericsson can supply such filters. Operators should consult the GSM equipment supplier to obtain actual performance data on their equipment.

Blocking

In cases where WCDMA blocks GSM, ETSI stipulates (in GSM 05.05) an 8 dBm blocking level for GSM 900, and 0 dBm for GSM 1800. All Ericsson GSM base stations have been designed to handle these levels, providing blocking levels of 16 dBm.

Similarly, in cases where GSM blocks WCDMA, 3GPP (TS25.104) currently specifies a –15 dBm blocking level at 6 dB threshold degradation for GSM 900 and GSM 1800 TX frequencies. The Ericsson family of WCDMA base stations has been designed to handle GSM transmit signals that yield 20 dBm blocking levels.

Spurious emission

Spurious emissions degrade system selectivity, because

- the transmitter generates signals outside the allocated frequency slot (transmitter spurious); or
- strong input signals on non-receiver frequencies degrade receiver sensitivity.

For spurious emission from WCDMA in the GSM 900 and 1900 receiver, 3GPP (TS25.104) specifies –98 dBm/100 kHz. Assuming 30 dB antenna isolation, the Ericsson WCDMA RBS 3000 family typically has –108 dBm/100 kHz.

Similarly, for spurious emission from GSM 900 and 1800 in the WCDMA RX band, ETSI Phase 1 specifies (in GSM 05.05) –30 dB/3 MHz peak value. ETSI Phase 2+ specifies –62 dBm/100 kHz mean value for co-existence and –96 dBm/100 kHz mean value for co-siting.

This is not an issue for GSM 900—thanks to the large distance, low-order intermodulation products are not generated in the WCDMA RX band. However, for GSM 1800, third-order intermodulation products might occur when
$WCDMA_{low\ edge} < 2*f_2 - f_1 < WCDMA_{high\ edge}$

If transmitter combining is not employed for GSM 1800, then intermodulation products can be ignored for WCDMA RX. Likewise, intermodulation products can be ig-

nored if the GSM 1800 TX frequency band is less than 40 MHz, since they do not satisfy the above condition. However, the products of third-order intermodulation are a problem if
- the above condition is filled;
- transmitter-combining is employed in the GSM 1800 base station; and
- the GSM TX and WCDMA RX and diplexed.

If the RBS 3000 does not employ ASC between the antenna and base station, then frequency planning is required to keep third-order IM (IM3) products from GSM 1800 away from the WCDMA RX band. With ASC, the worst-case sensitivity degradation is 1 dB.

Otherwise, if GSM 1800 TX and RBS 3000 RX are not diplexed to the same antenna, then any products of third-order intermodulation can be treated as wideband noise. Figure 10 shows how three intermodulation products degrade RBS 3000 sensitivity.

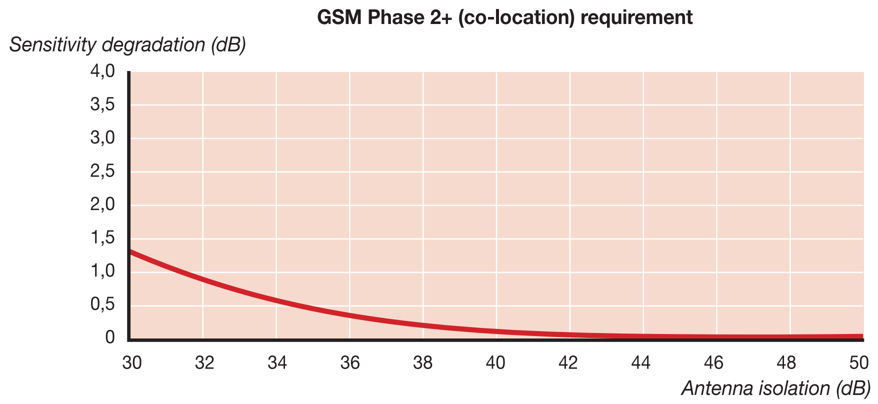


Figure 10
Sensitivity degradation as a function of antenna isolation according to GSM Phase 2+.

ETSI Phase 1 specifies WCDMA sensitivity degradation of 45 dB, assuming 30 dB antenna isolation. For non-Ericsson equipment, Phase 1 GSM base station complying with –30 dBm/3 MHz, the spurious emission will severely degrade RBS 3000 sensitivity. An uplink filter can be added to the GSM RBS or proper site solution can be deployed.

For co-existence, Phase 2+ specifies RBS 3000 sensitivity degradation of 29 dB; for co-location, RBS 3000 sensitivity degradation of 1.4 dB, again assuming 30 dB antenna isolation.

Operators should contact the manufacturer of non-Ericsson GSM equipment to obtain actual spurious emission performance.

Conclusion

Ericsson supports all major mobile system standards and can thus provide every conceivable co-siting solution. In general, two basic techniques are used in RF co-siting: filter combiners and hybrid combiners.

A filter combiner has two or more filter branches connected to a common port. Each filter branch is designed to have a defined frequency range that enables signals from each branch to be combined on the common port without signals from one branch leaking into another branch.

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An antenna-sharing unit uses hybrid combiner techniques to share the RX signal from the GSM base station to another RBS.

Filter combiners for co-siting purposes include duplex and diplex filters. Duplex filters combine the TX and RX signals of a specific frequency band into a common signal. Diplex filters further combine combined TX/RX signals from separate frequency bands into a common signal.

The two main TDMA-GSM co-siting solutions are TDMA-GSM single band and TDMA-GSM dual band. Likewise, the two main GSM-WCDMA co-siting solutions are antenna sharing and feeder sharing.

Radio performance can be affected when different systems are co-sited. Therefore, special attention should be paid to the guard band and carrier separation, isolation between systems, transmitter noise, intermodulation products, receiver blocking and spurious emissions. Ericsson has extensive know-how and experience of dealing with these matters individually and in combination.