Fundamentals of Performing Electromagnetic Compatibility Analysis

USTTI Spectrum Management Course

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OVERVIEW

Definitions and Fundamental Relationships

- Analysis Objective and Approach
- Interference Mechanisms
- Types of Analysis
- Interference Protection Criteria
- Propagation Loss Modeling
- Frequency Dependent Rejection
- Example Problem Using MSAM

DEFINTIONS

- Electromagnetic compatibility (EMC) is the ability of electronic equipment to operate in the attended operational environment without causing unacceptable degradation to other equipment or receiving unacceptable degradation from other equipment.

- Electromagnetic interference (EMI) is defined as an undesired signal or noise that causes degradation in system performance.

- EMC encompasses the discipline of controlling or preventing the degrading effects of EMI.

FUNDAMENTAL RELATIONSHIPS

- EMI occurs between a transmitter and receiver.
- The methods of coupling between the transmitter and receivers include:

  - signals radiated through space;
  - signals conducted through cables or wires.

FUNDAMENTAL RELATIONSHIPS

- Degradation occurs in a receiver when an interfering signal (I) exceeds the threshold of the receiver.
- The interference threshold can be defined in terms of a signal-to-interference (S/I), carrier-to-interference (C/I) or interference-to-noise (I/N) ratio at which the performance of a system changes from an acceptable to unacceptable level.

Link Budget Analysis

- As the name implies, a link budget is an accounting of all the gains and losses in a transmission system.
- The link budget looks at the elements that will determine the signal strength arriving at the receiver. The link budget may include the following items:
  - Transmitter power
  - Antenna gains (receiver and transmitter)
  - Antenna feeder losses (receiver and transmitter)
  - Path losses
- The link budget will take the form of the equation below:

Received Power = Transmitted Power + Gains - Losses

FUNDAMENTAL RELATIONSHIPS

The desired signal power (S) or carrier power (C) level can be computed using the following equation:

$$S \text{ or } C = Pt + Gt + Gr - Lp$$

where:

Pt is the transmitter power level (dBm)
Gt is the transmit antenna gain (dBi)
Gr is the receive antenna gain (dBi)
Lp is the propagation loss between the desired transmitter and receiver (dB)

FUNDAMENTAL RELATIONSHIPS

The interfering signal power level (I) can be computed using the following equation:

$$I = Pt_i + Gt_i + Gr - Lp_i - FDR - Ls$$

where:

Pt_i is the interfering transmitter power level (dBm)

Gt_i is the gain of the interfering transmitter (dBi)

Gr is the antenna gain of the victim receiver (dBi)

Lp_i is the propagation loss between the interfering transmitter and victim receiver (dB)

FDR is the frequency dependent rejection (dB)

Ls are any additional losses (dB)

FUNDAMENTAL RELATIONSHIPS

- At frequencies above approximately 400 MHz, the noise floor of most conventional receivers is established by the thermal noise generated inside the receiver:

  $$N = 10 \text{ Log } (kTB) + NF = -114 + 10 \text{ Log } (B) + NF$$

  where:

  N is the noise power (dBm);
  k is Boltzman's constant (1.38×10^{-23} J/K);
  T is the receiver temperature (290 K);
  B is the receiver bandwidth (MHz);
  NF is the receiver noise figure (dB).

- Below 400 MHz external (i.e., environmental) noise received through the antenna becomes the dominant source:

  - atmospheric noise;
  - galactic noise;
  - man-made noise.

ANALYSIS OBJECTIVE

The objective of an EMC analysis depends on the evolutionary life cycle of the system and can encompass the following areas:

- selecting a frequency band or determining the suitability of a designated band for the system;
- analyzing the system operating characteristics to determine their conformance to EMC specifications or standards;
- analyzing the system to identify potential EMI interactions with the operating environment;
- recommending designs or approaches that will minimize the potential for EMI;
- determining frequency and distance separation requirements, develop compatible frequency plans and provide operation configurations and constraints to promote EMC;
- determining coordination distances to protect systems.

INTERFERENCE MECHANISMS

- Co-Channel Interference: occurs when energy from the emission spectrum of a transmitter that overlaps the passband of the receiver, causing EMI.

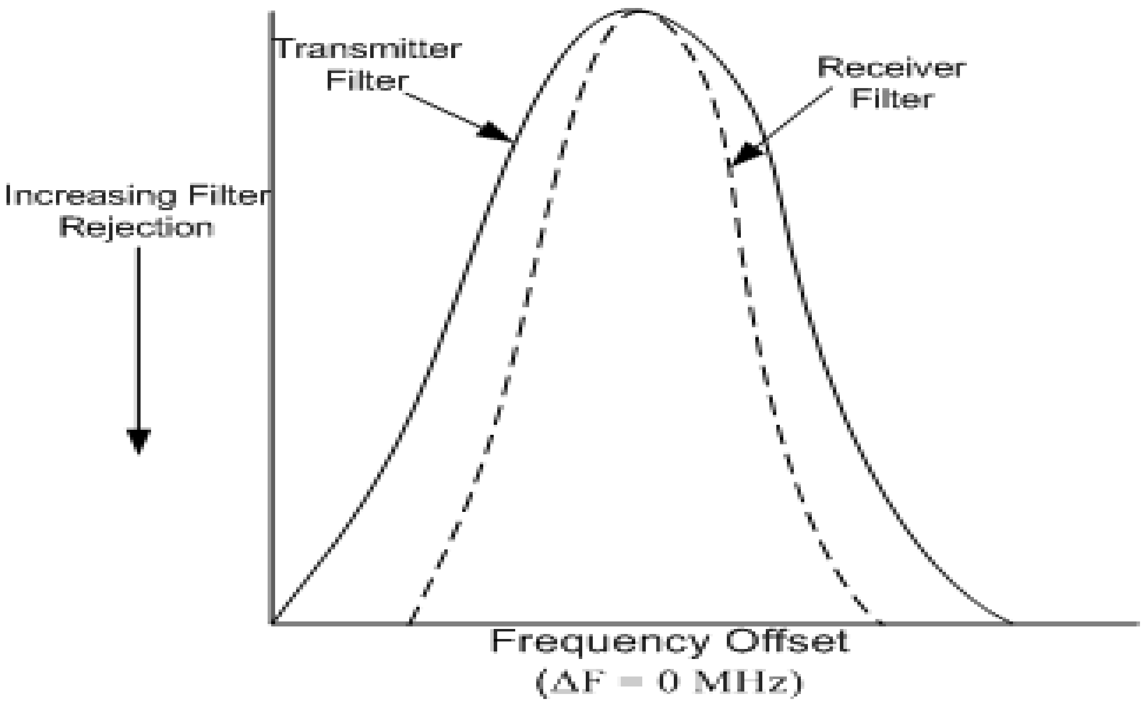
- Adjacent Channel Interference: occurs when broadband noise or energy contained in the emission sidebands of a wideband signal from a transmitter, whose frequency is relatively close to the tuned frequency of the receiver, causing EMI.

- Spurious Emissions Interference: occurs when discrete, narrowband emissions generated by local oscillators, mixers, phase detectors, or power amplifiers fall within the receiver passband, causing EMI.

- Harmonic Frequency Interference: is a special case of spurious emissions interference caused by undesired emissions that occur at integer multiples of the fundamental frequency of an interfering transmitter.

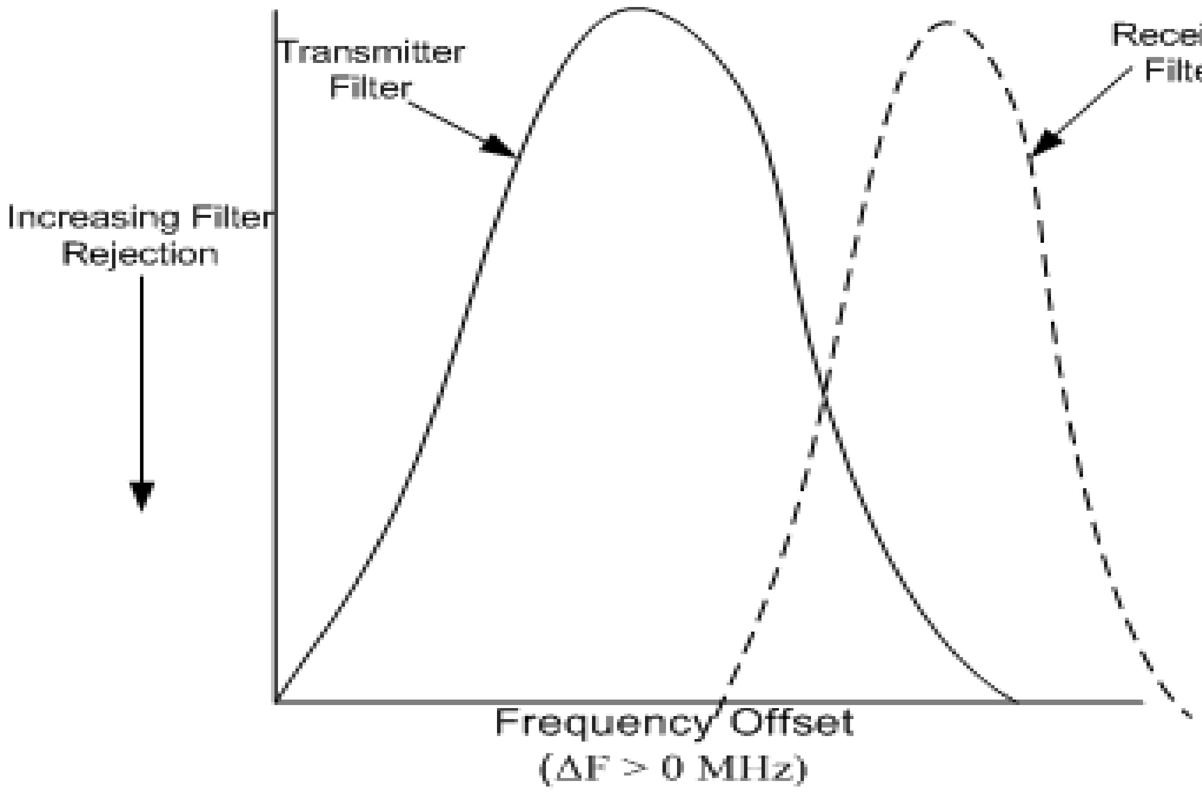
Co-Frequency Interference

Occurs when energy from the emission spectrum of a transmitter overlaps the receiver, causing EMI.



Adjacent Band Interference

Occurs when energy contained in the emission sidebands from a transmitter overlaps the receiver, causing EMI.



INTRASITE AND INTERSITE ANALYSES

- EMC analyses can be classified into two broad general categories, each with its own set of analysis requirements, conditions, and objectives:

  - intrasite analyses (co-site);
  - intersite analyses.

- In general, an intersite analysis is differentiated from a intrasite analysis by the size of the geographic area under examination.

INTRASITE ANALYSES

- A intrasite analysis considers non-linear interactions among a number of collocated systems.
- The interactions include the following non-linear interference mechanisms:
  - receiver desensitization;
  - gain compression;
  - intermodulation;
  - near-field antenna coupling conditions;
  - high power effects (cable/case penetration, receiver saturation/burnout).
- Generally a intrasite environment occurs when antennas for systems are located on the same platform such that the distances between them are relatively small (i.e., ship, tower, or building rooftop).

INTERSITE ANALYSES

In an intersite analysis systems operate in the environment with distances between systems that are great enough to neglect non-linear interference mechanisms, near-field coupling, and high-power effects.

For an intersite analysis, the interference mechanisms of major concern include:

- co-channel interference
- adjacent channel interference
- spurious emission interference (including harmonics);
- spurious response interference.

INTERFERENCE PROTECTION CRITERIA

- Interference Protection Criteria (IPC) is a relative or absolute interfering signal level defined at the receiver input, under specified conditions, such that the allowable performance degradation is not exceeded.

- IPC are usually specified as an absolute interference power (I) or ratios of desired signal to interference (S/I or C/I) or a ratio of interference to noise (I/N).

- IPC can be specified for single-entry interfering signals or aggregate interfering signals as well as short-term and long-term interference events.

- IPC can also be dependent on the specific type of interfering signal:

  - continuous wave
  - pulse
  - noise

INTERFERENCE PROTECTION CRITERIA

- The primary sources of IPC include international and domestic standards.
- Two reference reports that specify IPC:
  - JSC-CR-10-004 Communications Receiver Performance Degradation Handbook
  - NTIA Report 05-432 Interference Protection Criteria Phase 1 - Compilation of Existing Sources

PROPAGATION LOSS MODELING

- When the transmitting and receiving antennas are within line-of-sight of each other freespace propagation loss applies:

$$L_{FS} = 20 \text{ Log } F + 20 \text{ Log } D + 32.45$$

where

L_{FS} is the freespace propagation loss (dB);
F is the frequency (MHz);
D is the separation distance between the transmitter and receiver (km).

- For separation distances between the transmitter and receiver of less than 1 km most propagation models default to freespace propagation.

PROPAGATION LOSS MODELING

- In performing EMC analysis there are two broad classes of propagation models:
  - area propagation models;
  - terrain dependent propagation models.
- The NTIA Irregular Terrain Model (ITM):
  - Area Mode used for analysis of mobile systems;
  - Point-to-Point Mode used for analysis of fixed systems.

FREQUENCY DEPENDENT REJECTION

- Frequency Dependent Rejection (FDR) is the rejection provided by a victim receiver to a interfering signal as a result of both limited bandwidth of the receiver with respect to the spectrum of the interfering signal and the off-tuning between the transmitter and receiver.
- FDR is the combination of two terms:
  - On Tune Rejection (OTR)
  - Off Frequency Rejection (OFR)

FREQUENCY DEPENDENT REJECTION

- OTR accounts for the rejection provided by the receiver as a result of the mismatch of the receiver bandwidth relative to the bandwidth of a co-tuned transmitter.
- OFR accounts for the rejection provided by a receiver as a result of off-tuning.
- To compute using the MSAM FDR program the transmitter emission spectrum and receiver selectivity must be defined.

EXAMPLE PROBLEM USING MSAM

- Perform an EMC analysis between two fixed point-to-point microwave systems.
- The MSAM models that will be used include:
  - Bearing Distance
  - ITM (Area and Point-to-Point Mode)
  - Terrain Profile

Proposed Transmitter Parameters

- **Location:** latitude 39º 24´ 00´´ N, longitude 077º 24´ 00´´ W
- **Site Elevation:** 300 Feet (91.44 meters)
- **Modulation:** 64 QAM
- **Tuned Frequency:** 8000 MHz
- **Transmitter Bandwidth:** 25 MHz
- **Transmitter Output Power (P_t):** 33.5 dBm
- **Antenna Type:** Shrouded Dish
- **Gain (G_t):** 43 dBi
- **Antenna Height:** 150 feet (45.72 meters)
- **Antenna Polarization:** Vertical
- **Antenna Pointing Angle:** 275º Relative to true north
- **Insertion Losses (L_{tx}):** 3 dB

Victim Receiver Parameters

Location: latitude 39º 23´ 59´´ N, longitude 077º 38´ 15´´ W
Site Elevation: 1040 Feet (316.992 meters)
Modulation: 64 QAM
Tuned Frequency: 8000 MHz
Nominal Unfaded Desired Signal Level (C): -29.5 dBm
Receiver Noise Figure (NF): 3.5 dB
Receiver IF Bandwidth (B): 25 MHz
Antenna Type: Standard Dish
Gain (G_r): 43 dBi
Antenna Height: 150 feet (45.72 meters)
Antenna Polarization: Vertical
Antenna Pointing Angle: 80º Relative to true north
Insertion Losses (L_{rx}): 4 dB

SINGLE ENTRY IPC

- **BIT ERROR RATE (BER) REDUCTION FROM 10^{-6} to 10^{-5}**
  - Telecommunications Industry Association Bulletin 10F specifies an I/N of -6 dB for digital systems

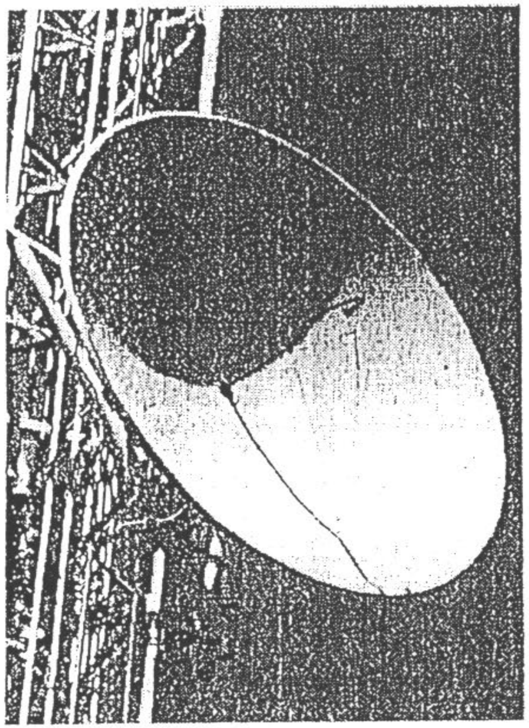
- **RECEIVER NOISE LEVEL**

  $$N = -114 + 10 \text{ Log } (25) + 3.5 = -96.5 \text{ dBm}$$

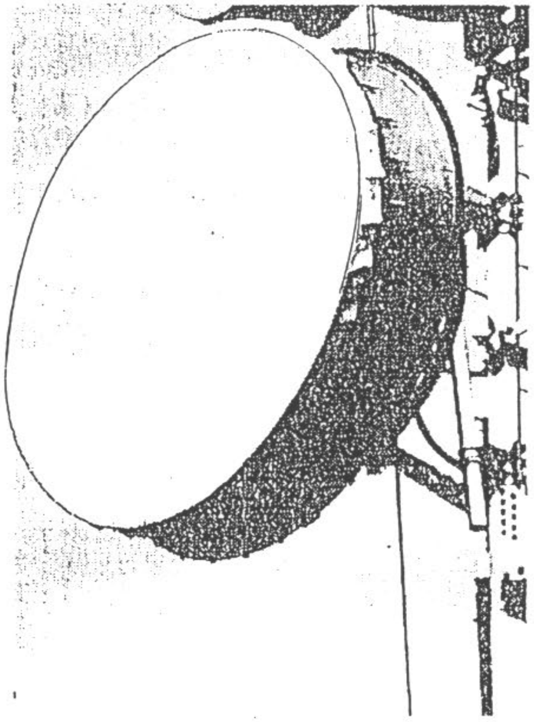
- **MAXIMUM PERMISSIBLE INTERFERENCE LEVEL**

  $$I_{MAX} = N + I/N = -96.5 - 6 = -102.5 \text{ dBm}$$

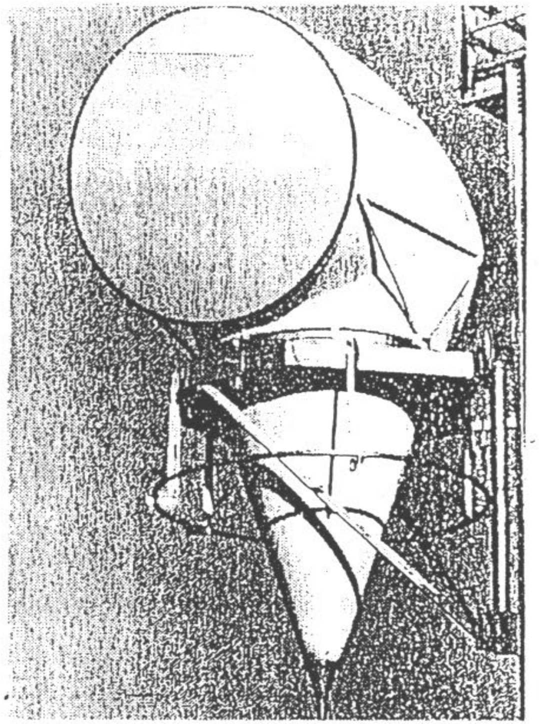
POINT-TO-POINT MICROWAVE SYSTEM ANTENNA TYPES



STANDARD DISK (STD)



SHROUDED DISH (SHD)



CONICAL HORN REFLECTOR (CHR)

RADIATION PATTERNS FOR STANDARD, CONICAL, AND SHROUDED FIXED POINT-TO-POINT ANTENNAS

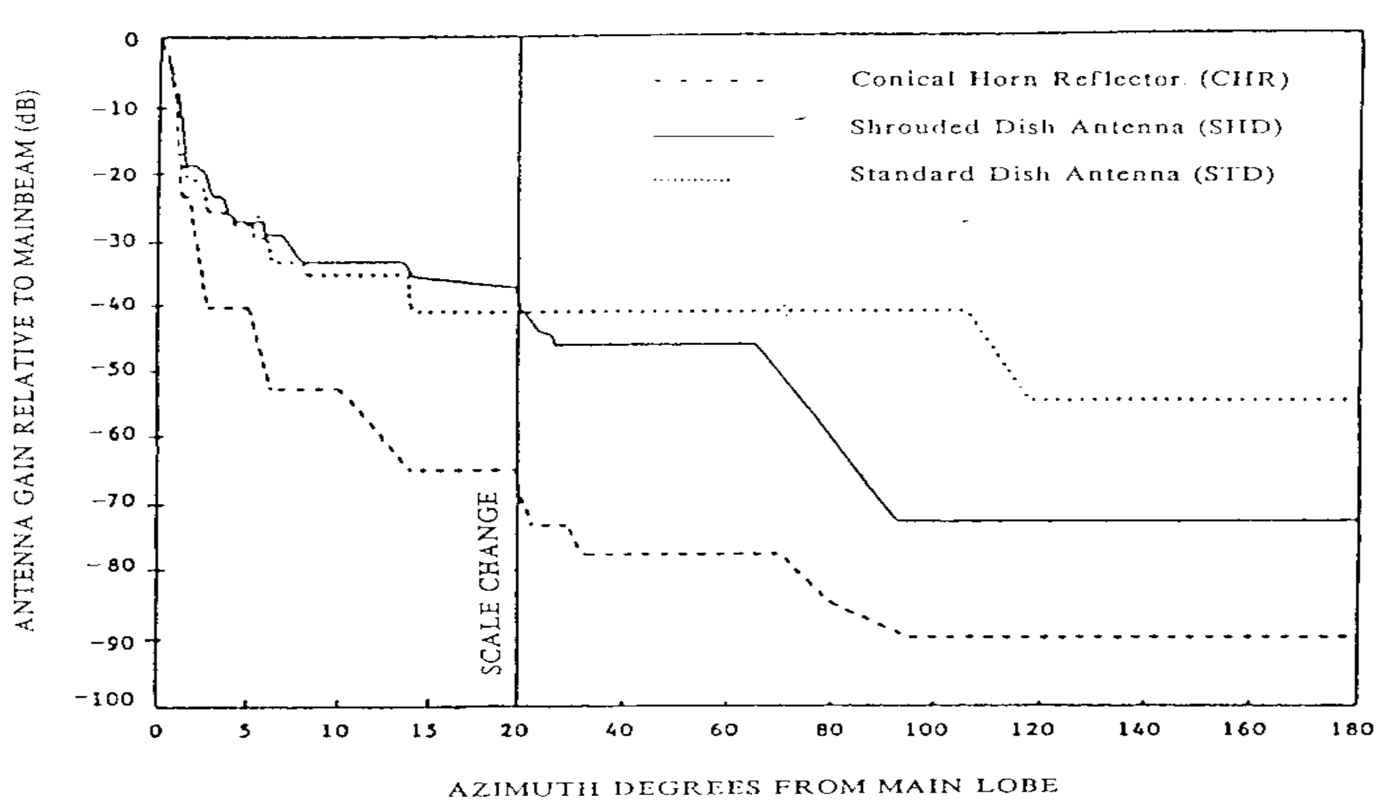
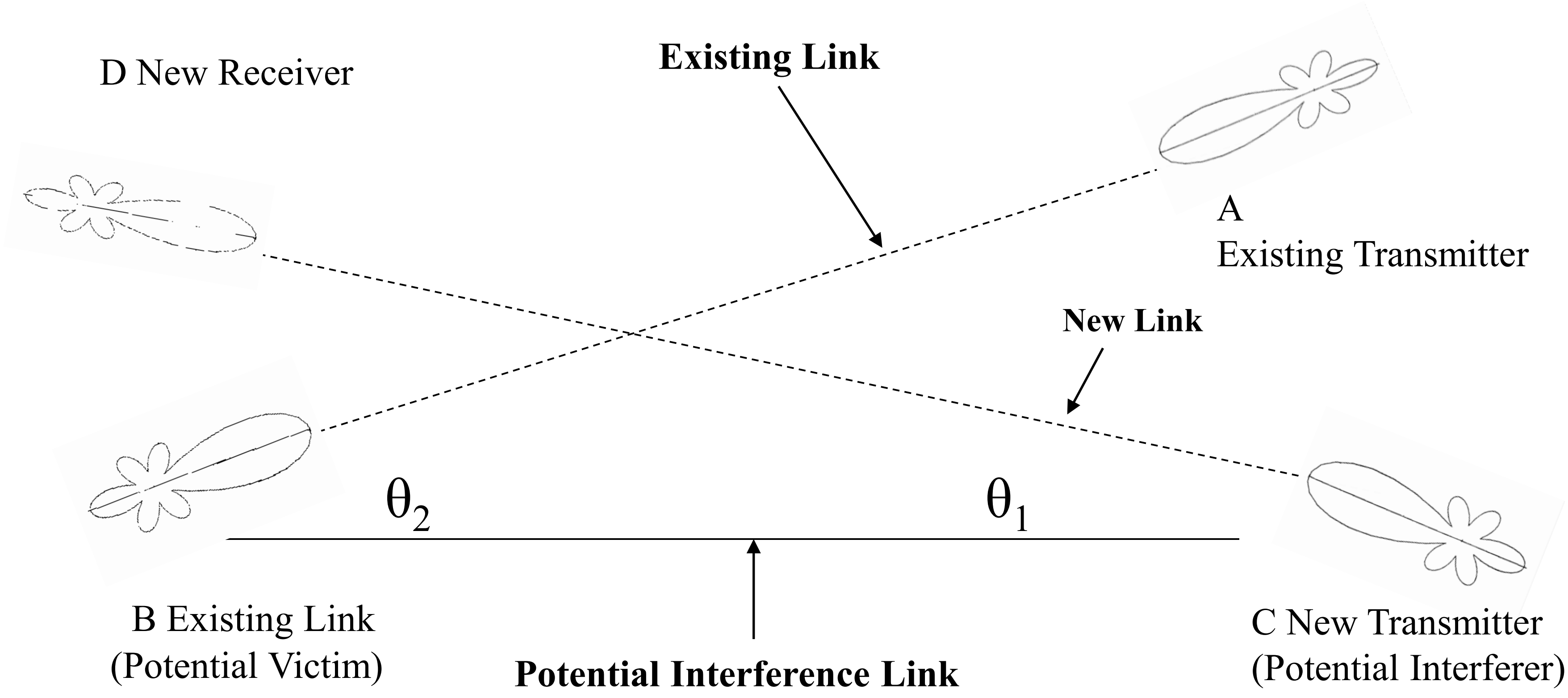


Figure 2. Typical Radiation Patterns

FIXED POINT-TO-POINT INTERFERENCE EXERCISE



CALCULATION OF C/I

The C/I for a terrestrial system can be related to the receiver performance in the presence of interference. This relationship is the relative levels of the received desired signal carrier power to the interference power at the input to the victim receiver.

$$C/I = C - Pt - Gt - Gr + Lp + FDR + Ltx + Lrx + Lpol$$

where:

C is the peak desired signal carrier power at the receiver input, in dBm
Pt is the peak transmitter power of the interfering transmitter, in dBm
Gt is the antenna gain of the interfering transmitter in the direction of the victim receiver, in dBi
Gr is the antenna gain of the victim receiver in the direction of the interfering transmitter, in dBi
Lp is the propagation path loss, in dB
FDR is the frequency dependent rejection between the transmitter and receiver, in dB
Ltx is the insertion losses from the interfering transmitter output to the antenna, in dB
Lrx is the insertion losses from the victim antenna to the receiver input, in dB
Lpol is the polarization mismatch loss, in dB

QUESTIONS

1) What is the required C/I?

2) What is the received C/I?

3) Will the new installed microwave link cause interference to the existing microwave link?