Contemporary Satellite Communications (SATCOM)

AICT 2014

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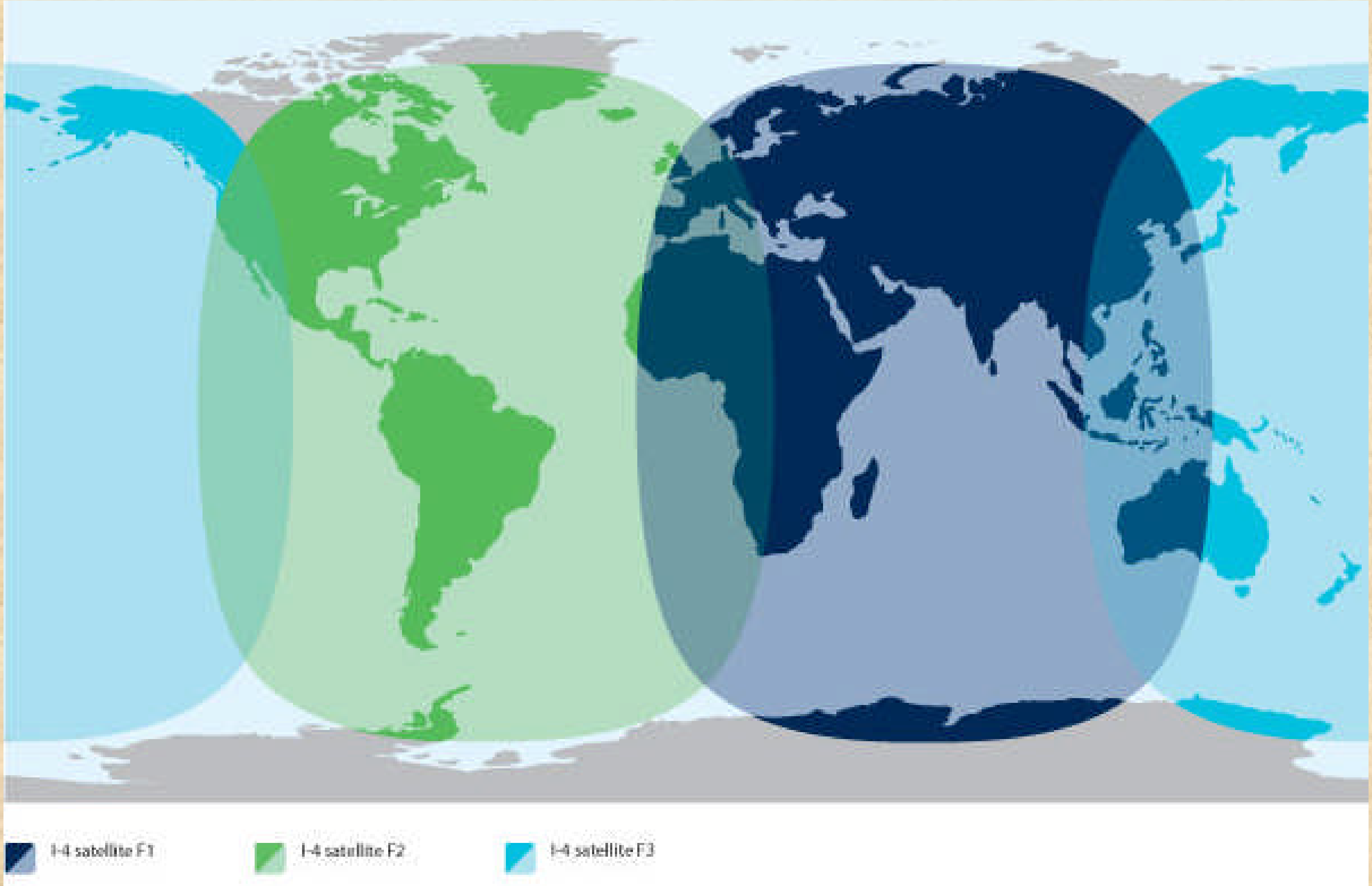
21st July 2014

Contents

Inmarsat



Inmarsat overview

- Geosynchronous satellites with 82 degrees North and South latitude coverage

- Operates in L (BGAN) and Ka (I-5, launched 30 June 2014) bands, with future expansion into S band

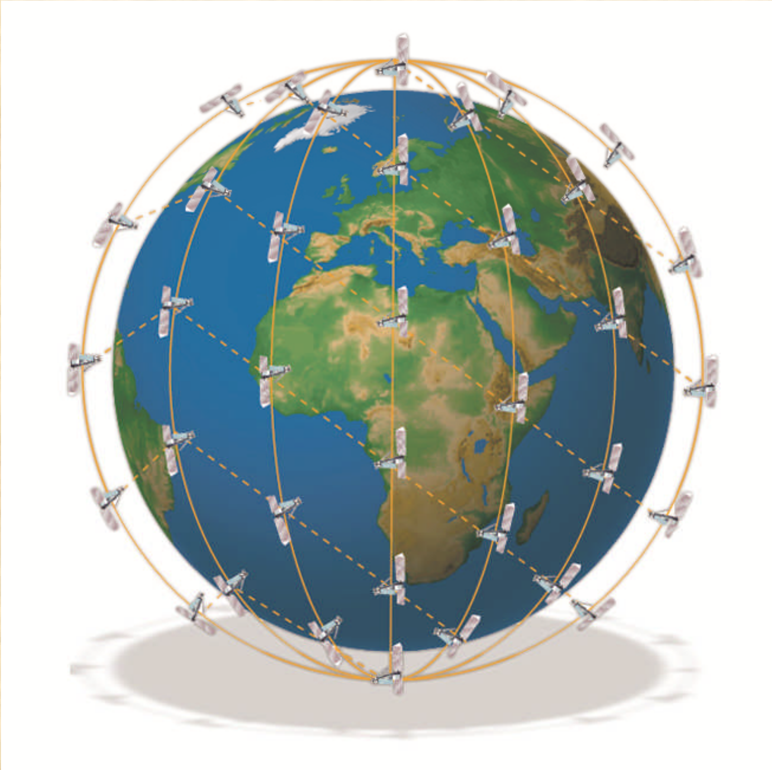
- Provides telephone and data services at a low rate

- Global (1), regional (19) and narrow (200) spot beams on each satellite

- Broadband Global Area Network (BGAN) uses narrow beams, up to 500 kbit/s

- Terminal interoperability with the WGS satellite fleet

Iridium

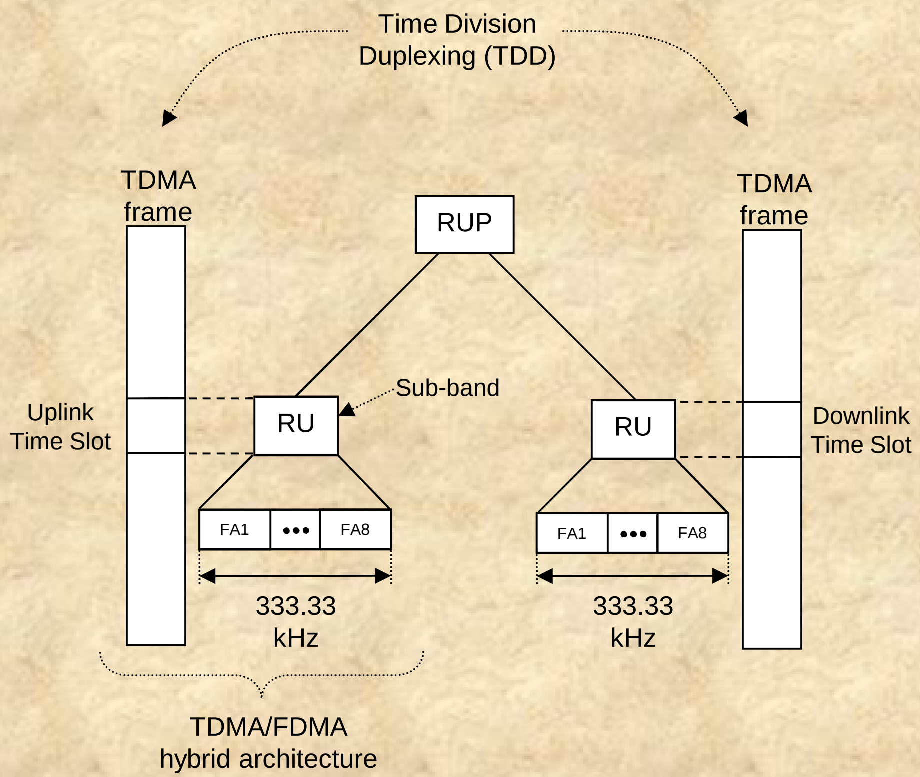


Iridium overview

- Operated by Iridium Communications Inc. in L band
- Provides the entire global coverage using 66 satellites in low Earth orbit
- Iridium NEXT is to replace the existing Iridium constellation by 2017
- Provides voice and data service, but at a low rate
- Implements the FDMA/TDMA hybrid architecture

Iridium overview

➢ FDMA/TDMA hybrid architecture



Skynet

Skynet overview

- Operated by Astrium Services on behalf of the UK Ministry of Defence (MoD) in UHF and X bands.

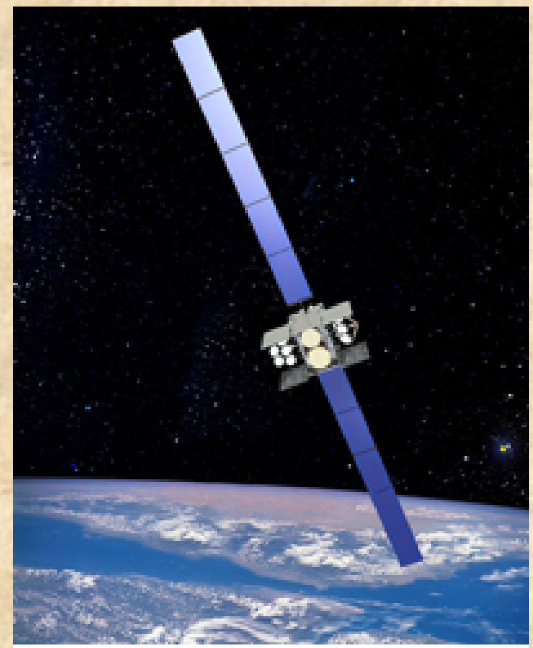
- Military X-band satellites designed to:
  - support smaller, low powered, tactical terminals
  - provide reliable communication channels

- Five generations of Skynet satellites, earliest launched in 1969, latest in 2012

- To date four ‘Skynet 5’ satellites have been launched with a 15 year life cycle

- ‘Skynet 5’ offers fully steerable downlink beams

Wideband Global SATCOM (WGS)



Wideband Global SATCOM Satellite

WGS overview

- A venture originally started by the US in 2001 under the name Wideband Gap-filler Satellite program

- Geosynchronous satellites operating in X and Ka bands with 65 degrees North and South latitude coverage

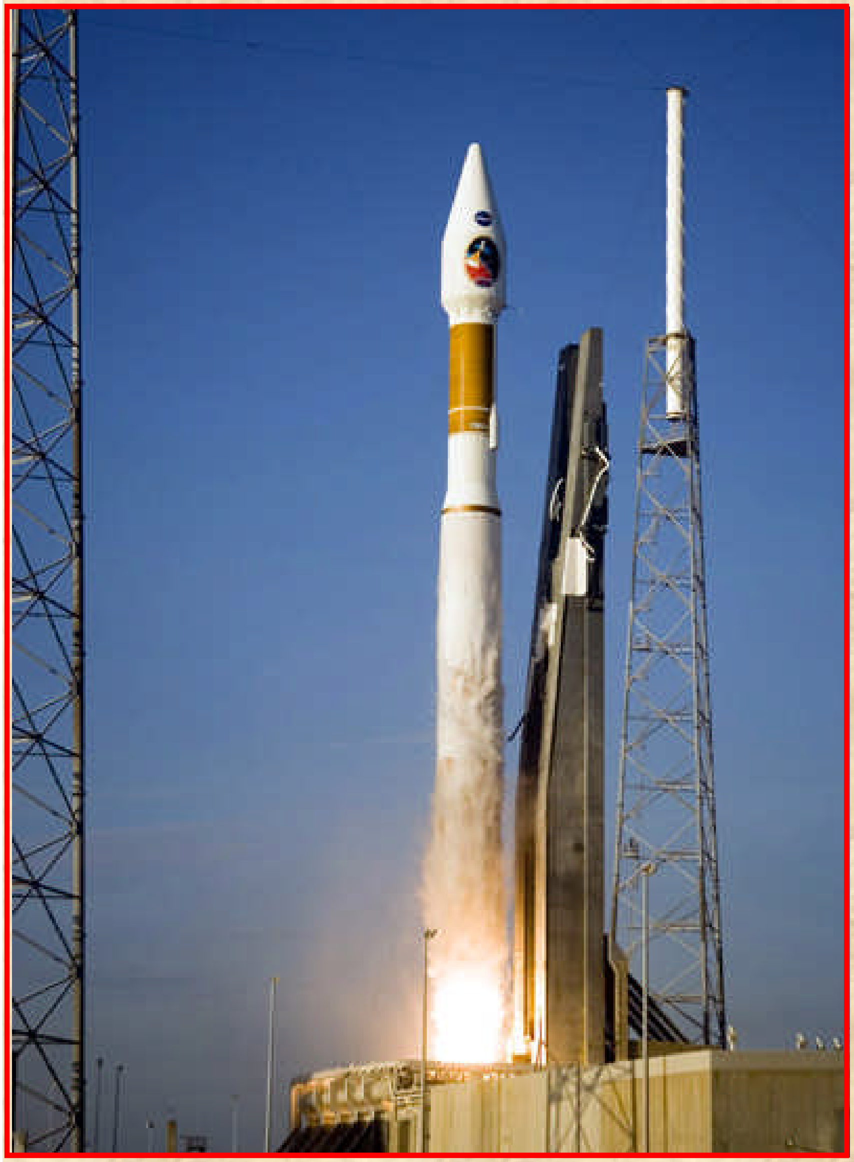
- A single WGS spacecraft has as much bandwidth as the entire existing DSCS constellation

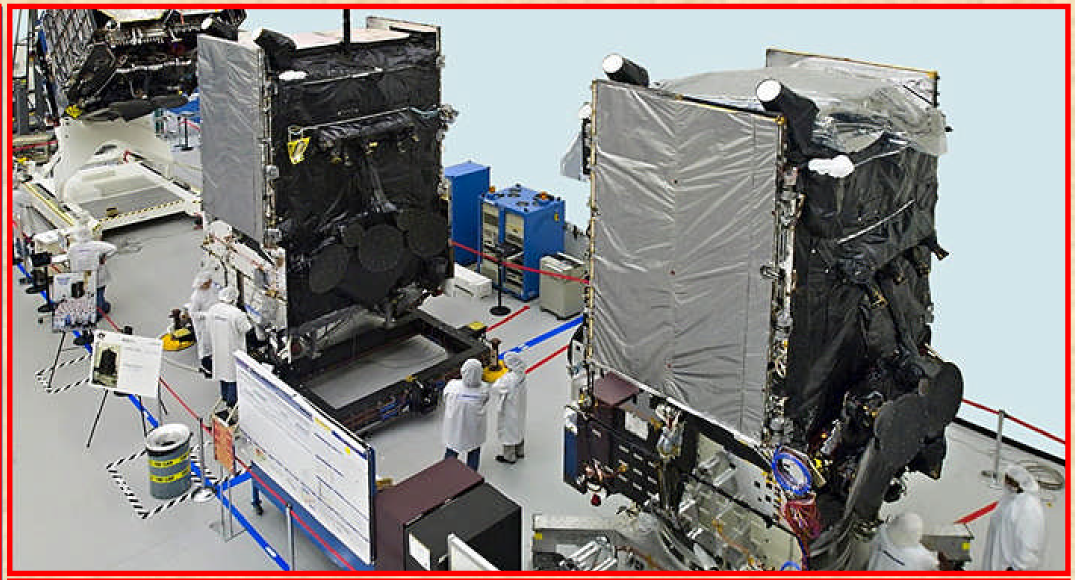
- Introduction of WGS greatly increases the C4ISR capability

- To date 6 WGS satellites have been launched, first in 2007, last in August 2013, with an expected14 year life cycle

- WGS 9, planned for launch in 2017, cost $620 million with contributions from: Canada, Denmark, Luxembourg, New Zealand and the Netherlands, in exchange for proportional access to the full constellation

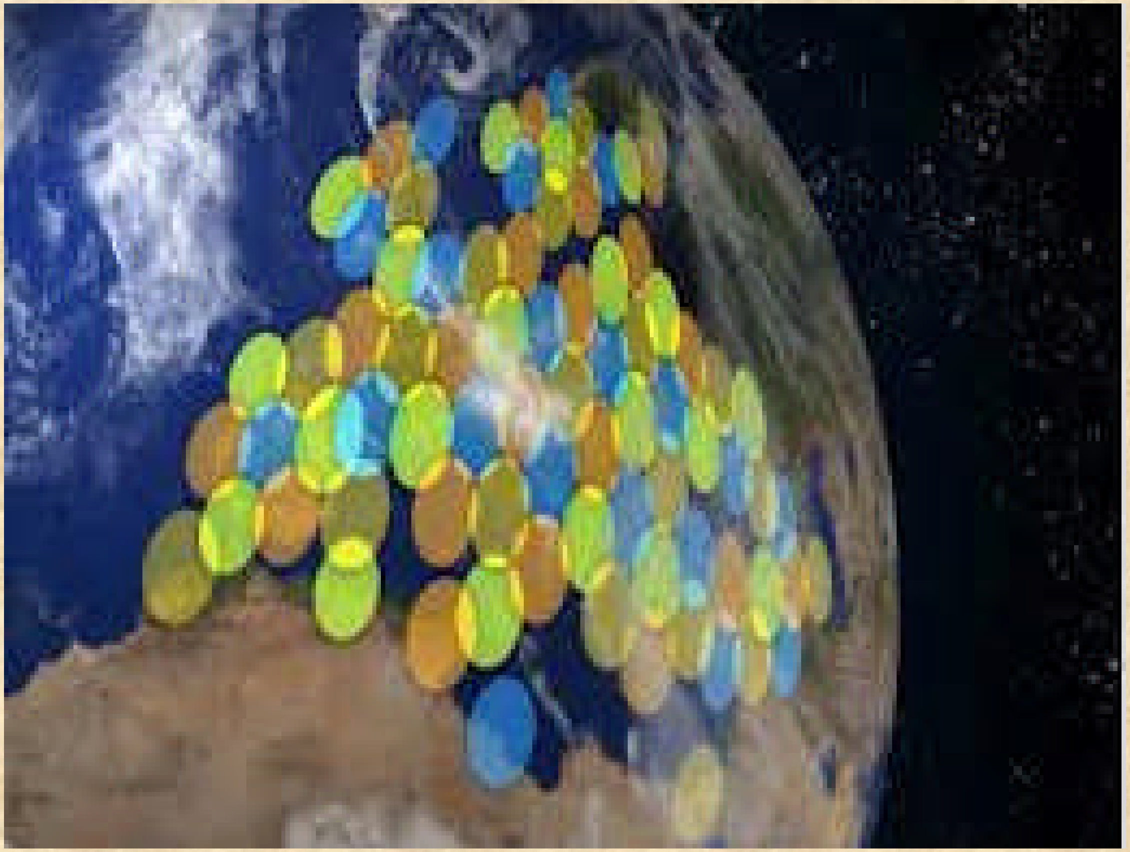
… WGS overview …





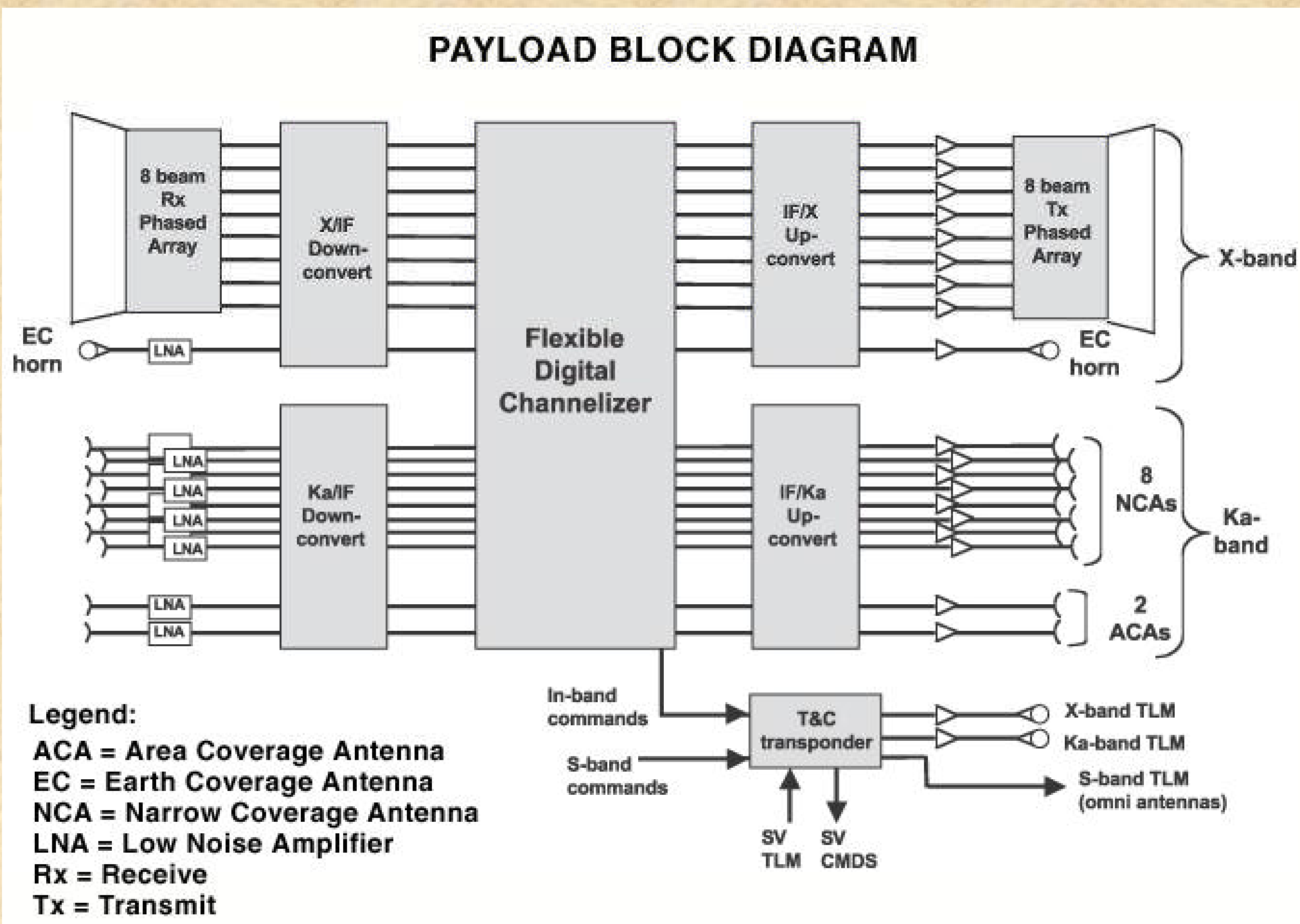
… WGS overview …

➢ A WGS satellite has a capability to alter the directivity of its **spot beams**. An exact pattern of spot beam illuminations at any one time is undisclosed.



… WGS overview

- There are 8 X band and 10 Ka band steerable beams



New Zealand Defence Force (NZDF) WGS timeline

➢ Request for Tender (RFT)

➢ 12 responses were received, 3 immediately invalidated and the remaining 9 examined in detail

➢ The outcome of the tender evaluations resulted in a decision to buy:

- 1 temporary anchor station (TAS) terminal from Rockwell Collins
- 2 deployable FA-240 land terminals from Ultra Gigasat Asia Pacific (GAP)
- 2 deployable HSS-130 land terminals also from GAP

Current WGS capability

- The **Rockwell Collins DKET** fixed terminal (arrived mid March 2014):

… Current WGS capability…

- The **Ultra GAP FA-240** deployable land terminals (two units arrived end of August):

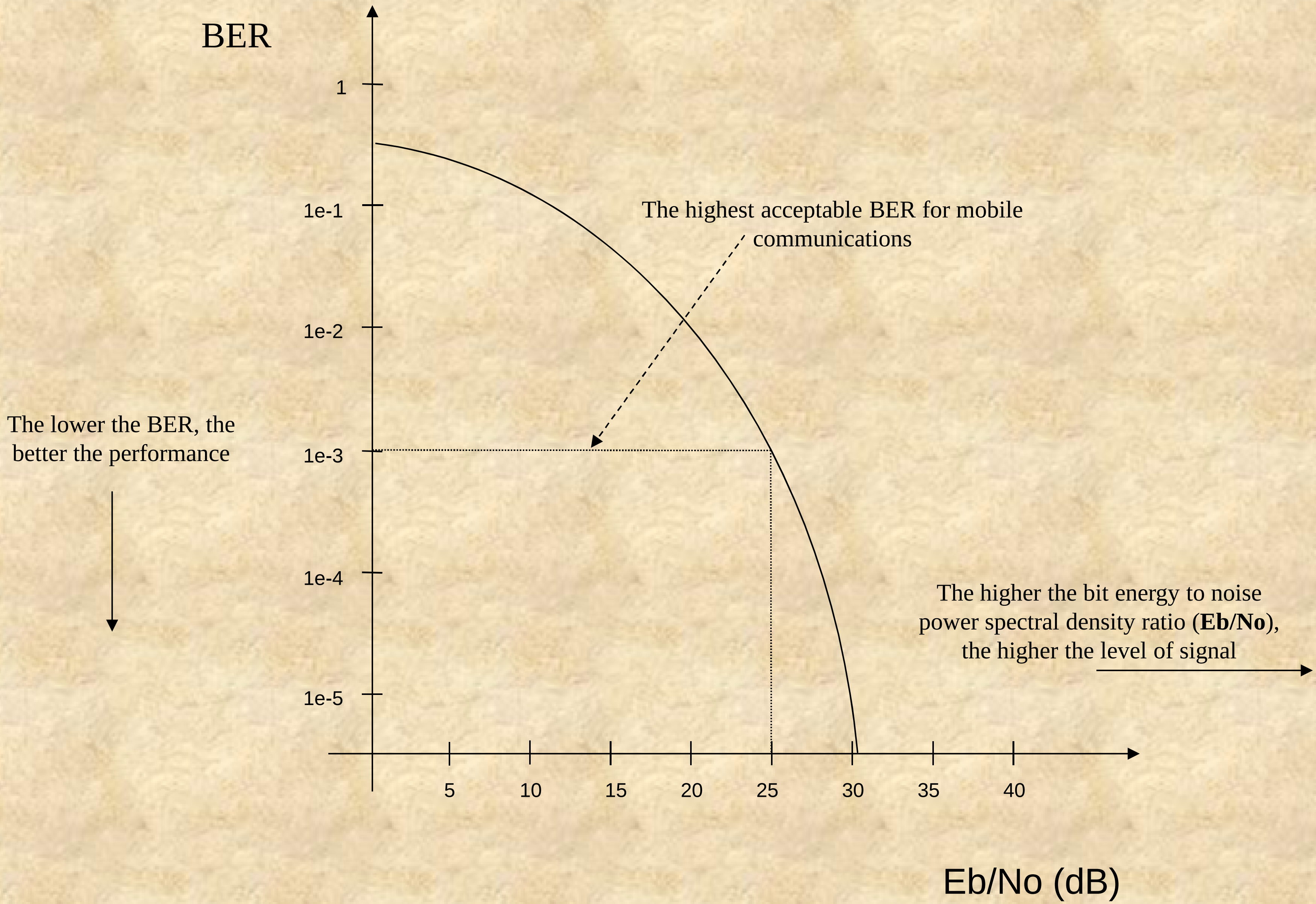
… Current WGS capability

➢ The **<u>Ultra GAP HSS-130</u>** deployable land terminals (two units arrived in September 2013):

FAT and ISAT procedure

- The FAT and ISAT involved the following tests:
  - ✓ Bit error rate (**BER**) tests of 5, 10, 15 and 20 minutes were conducted to obtain the BER graph at varying signal power while the overnight BER tests were used to test the system stability
  - ✓ Effective isotropic radiated power (**EIRP**) test
  - ✓ Gain to noise temperature (**G/T**) test
- EIRP and G/T tests verify that the delivered equipment's values match or exceed the advertised EIRP and G/T values
- The BER test is the most important test

… FAT and ISAT procedure …



… FAT and ISAT procedure …

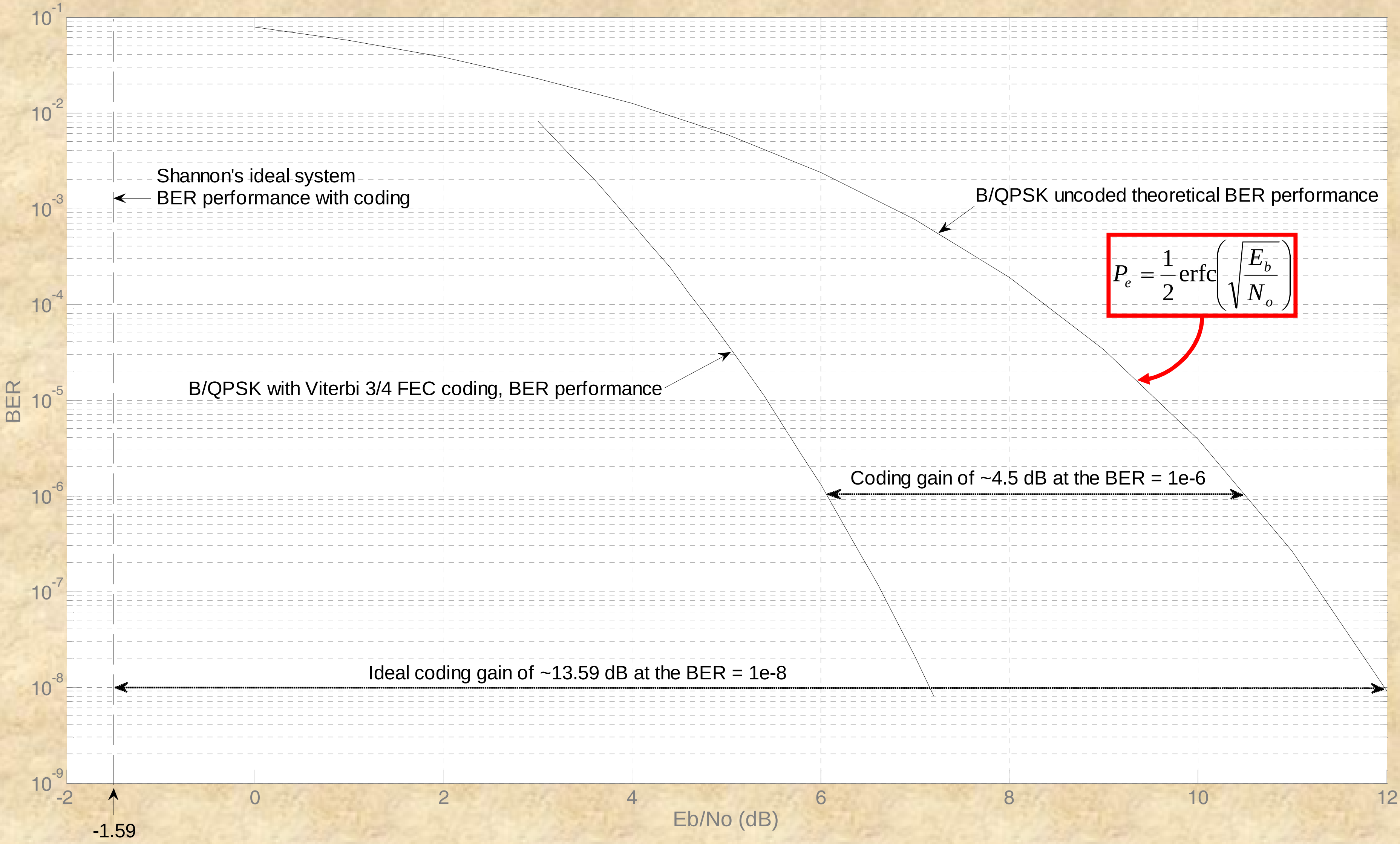
- The deployable and fixed terminals were operated in:
  - ✓ Frequency Division Multiple Access (FDMA) mode while implementing,
  - ✓ Quadrature Phase Shift Keying (QPSK) modulation and a given,
  - ✓ Forward Error Correction (FEC) code (TPC, Viterbi, Trellis etc.)

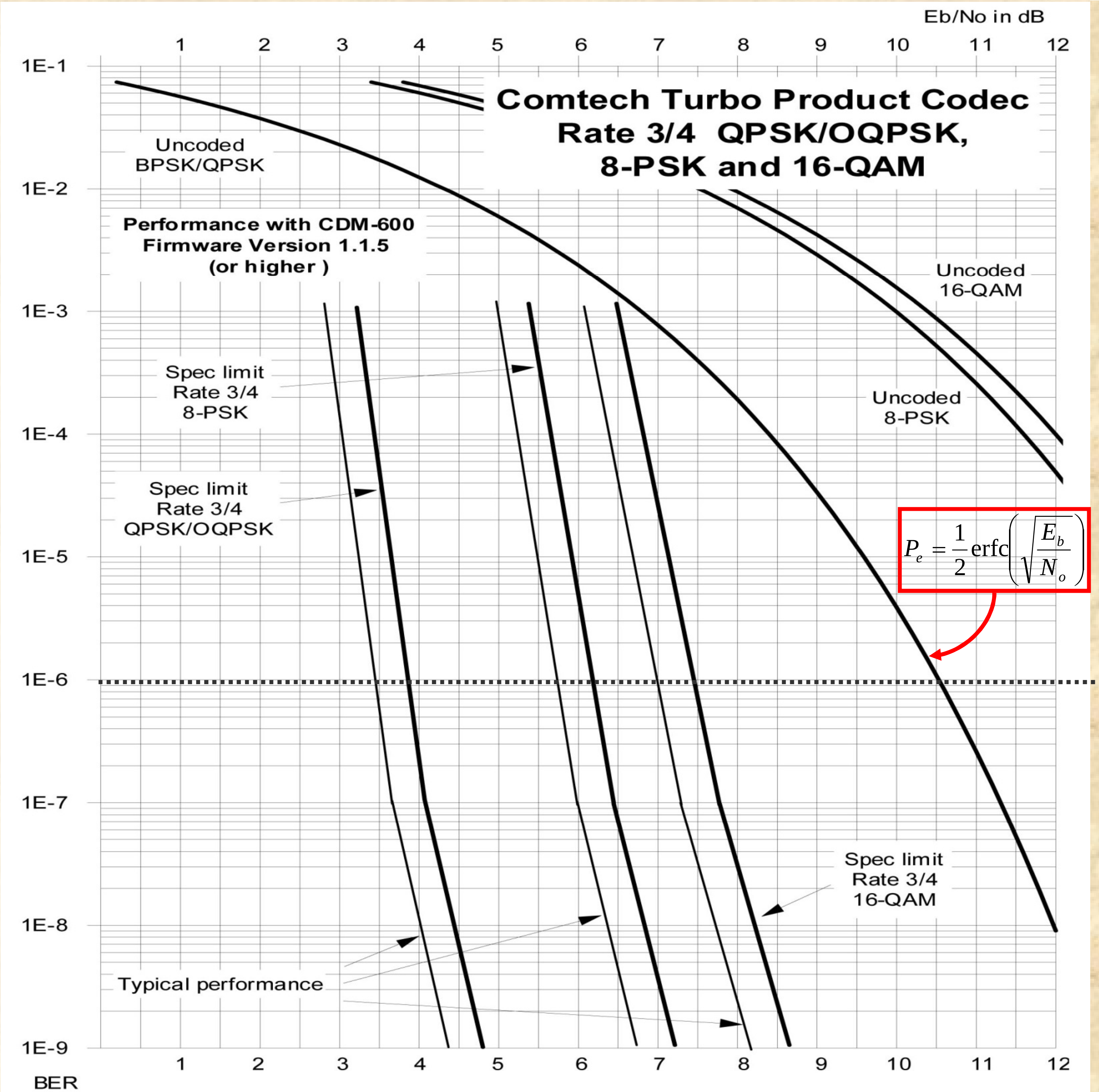
- Accordingly the following BER characteristics of a QPSK modulated communication system must be satisfied:

$$BER = P_e = \frac{1}{2}\operatorname{erfc}\left(\sqrt{\frac{E_b}{N_o}}\right)$$

FAT and ISAT procedure

$$C = \lim_{B \to \infty} \left\{ B log_2 \left(1 + \frac{E_b/T_b}{N_o B} \right) \right\} \rightarrow \frac{1}{T_b} = \frac{E_b}{N_o T_b \ln 2} \rightarrow \frac{E_b}{N_o} = \ln 2 = -1.59\ dB$$



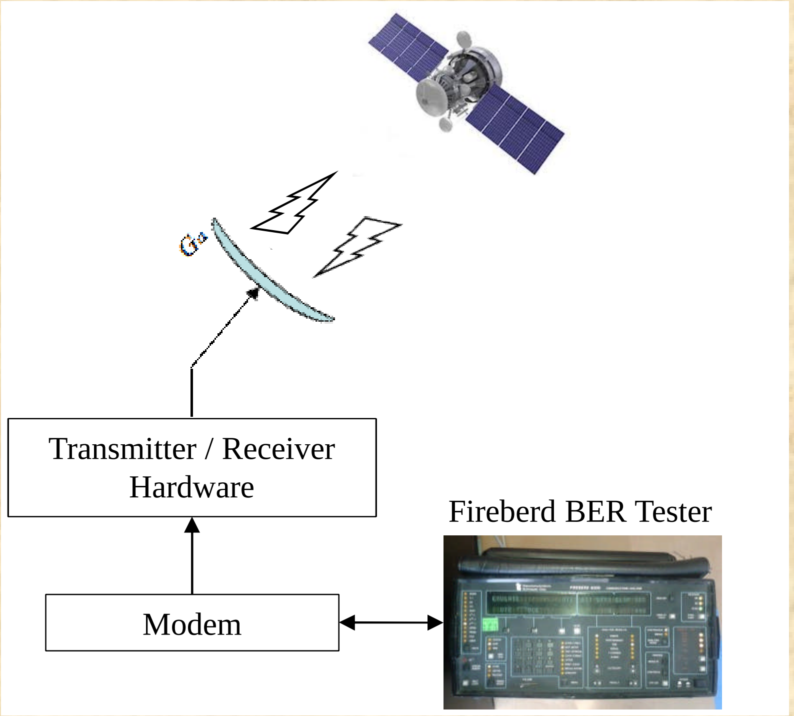


Lower limit on BER:

1e-6

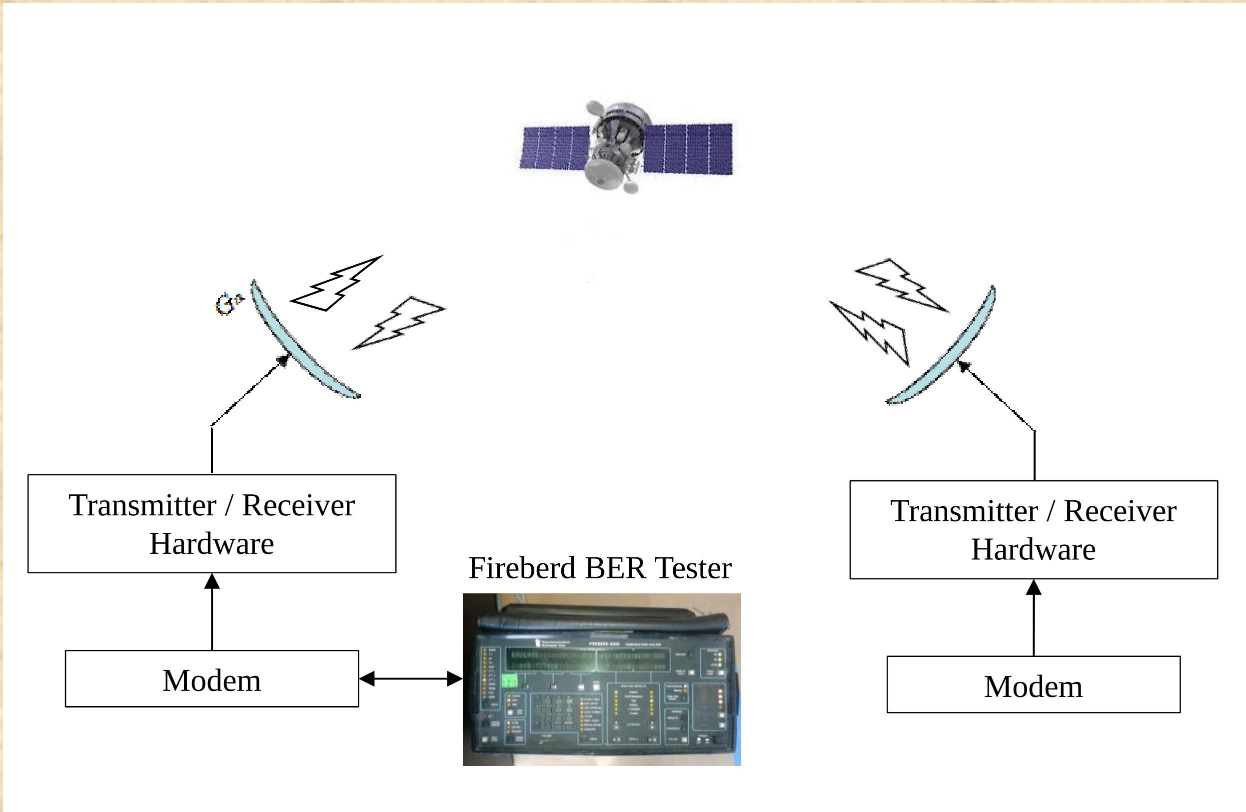
WGS digital communication system testing

- The loopback test of a terrestrial satellite communication system

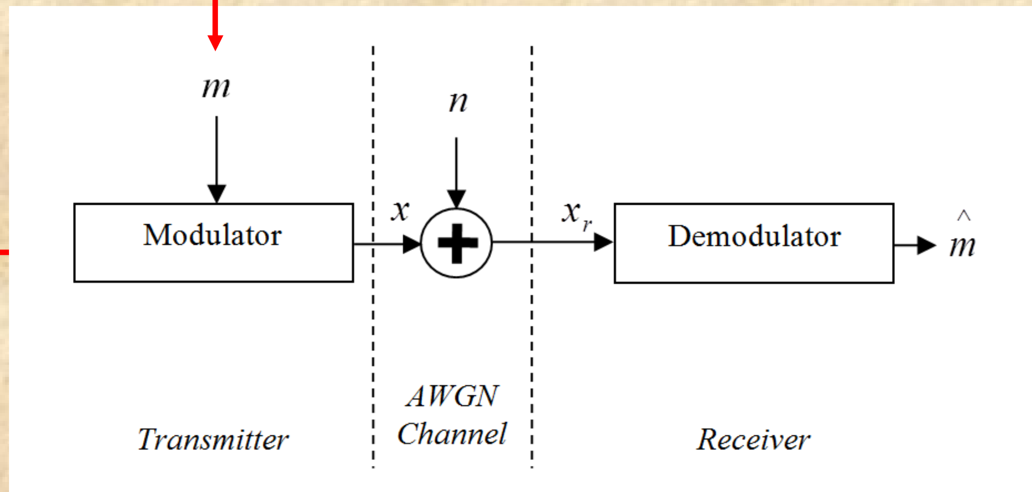


WGS digital communication system testing

➢ The **remote** loopback test of a terrestrial satellite communication system



Empirical BER evaluation

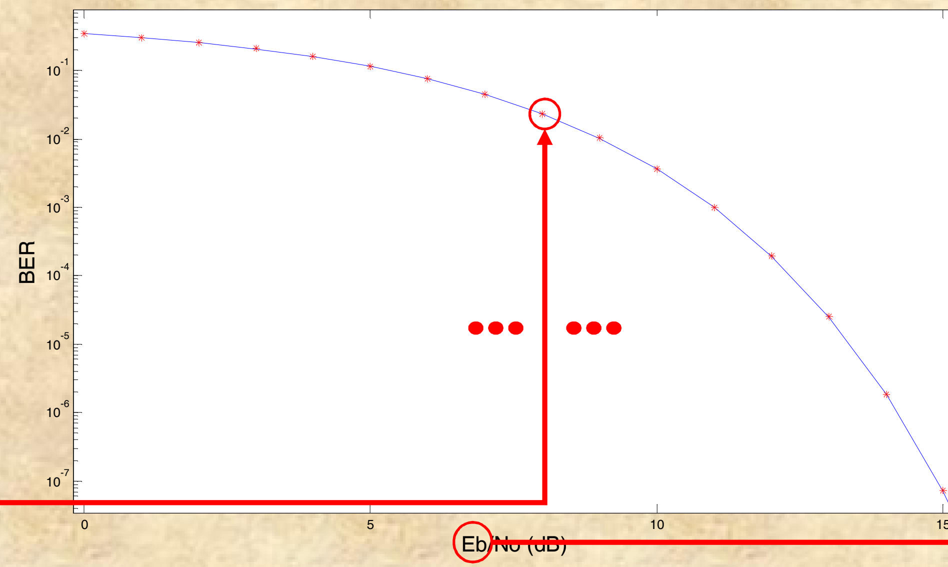


Compare bits

Sum errors

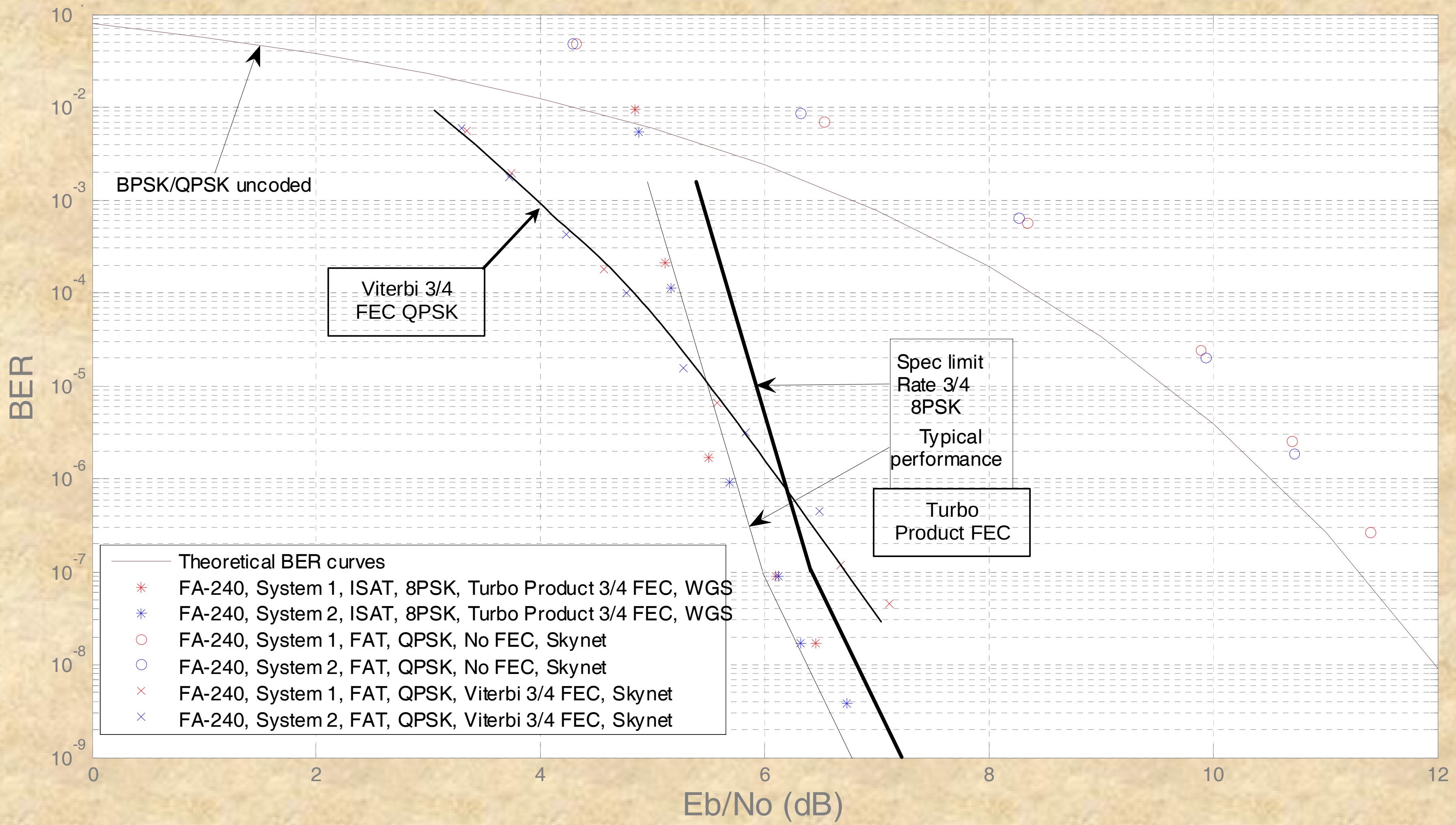
Divide by total number of bits

BER



FA240 FAT and ISAT BER results

- The Ultra Gigasat FA240 deployable land terminals (arrived end of August 2013):



HSS-130 ISAT BER results

- When transmitted signal power cannot be varied Eb/No is constant.

$$N = \frac{1}{BER}\left[-\ln(1-CL) + \ln\left(\sum_{k=0}^{E}\frac{(N*BER)^k}{k!}\right)\right]$$

$$N = \frac{1}{BER}[-\ln(1-CL)]$$

N x *BER* values

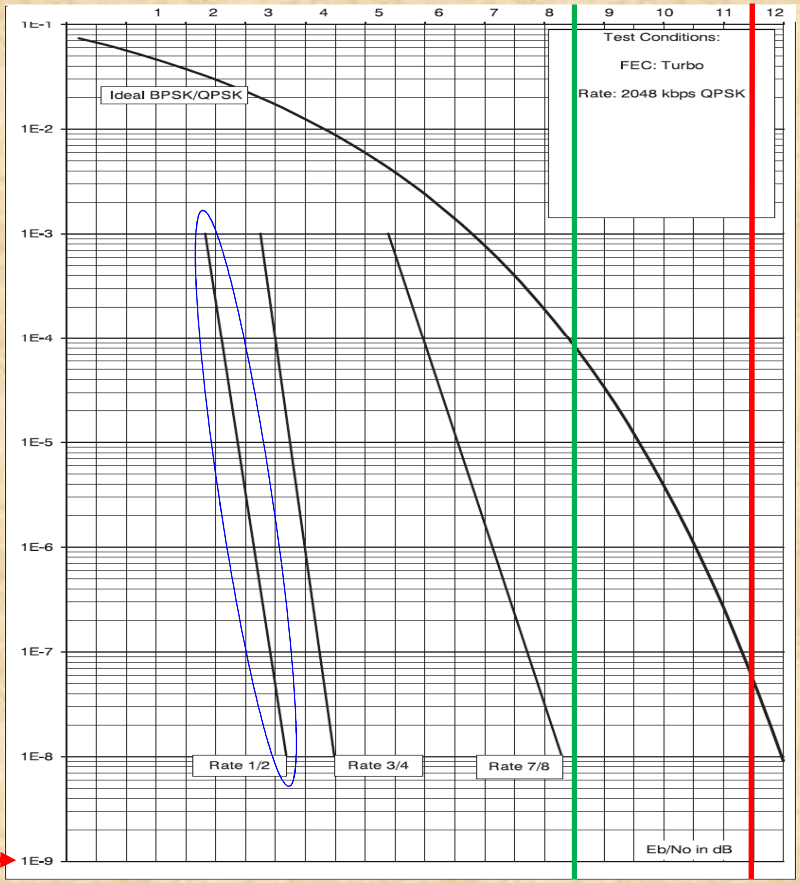
Errors	CL = 90%	CL = 95%	CL = 99%
0	2.3	3	4.61

- *N* = 11.0592 billion bits were processed with 0 errors at the Eb/No = 8.5 and 11.5 dB

- It can thus be stated that at Eb/No = 8.5 and 11.5 dB we are 99% confident that the actual system BER is below 10^{-9} as:

N x *BER* = 4.61

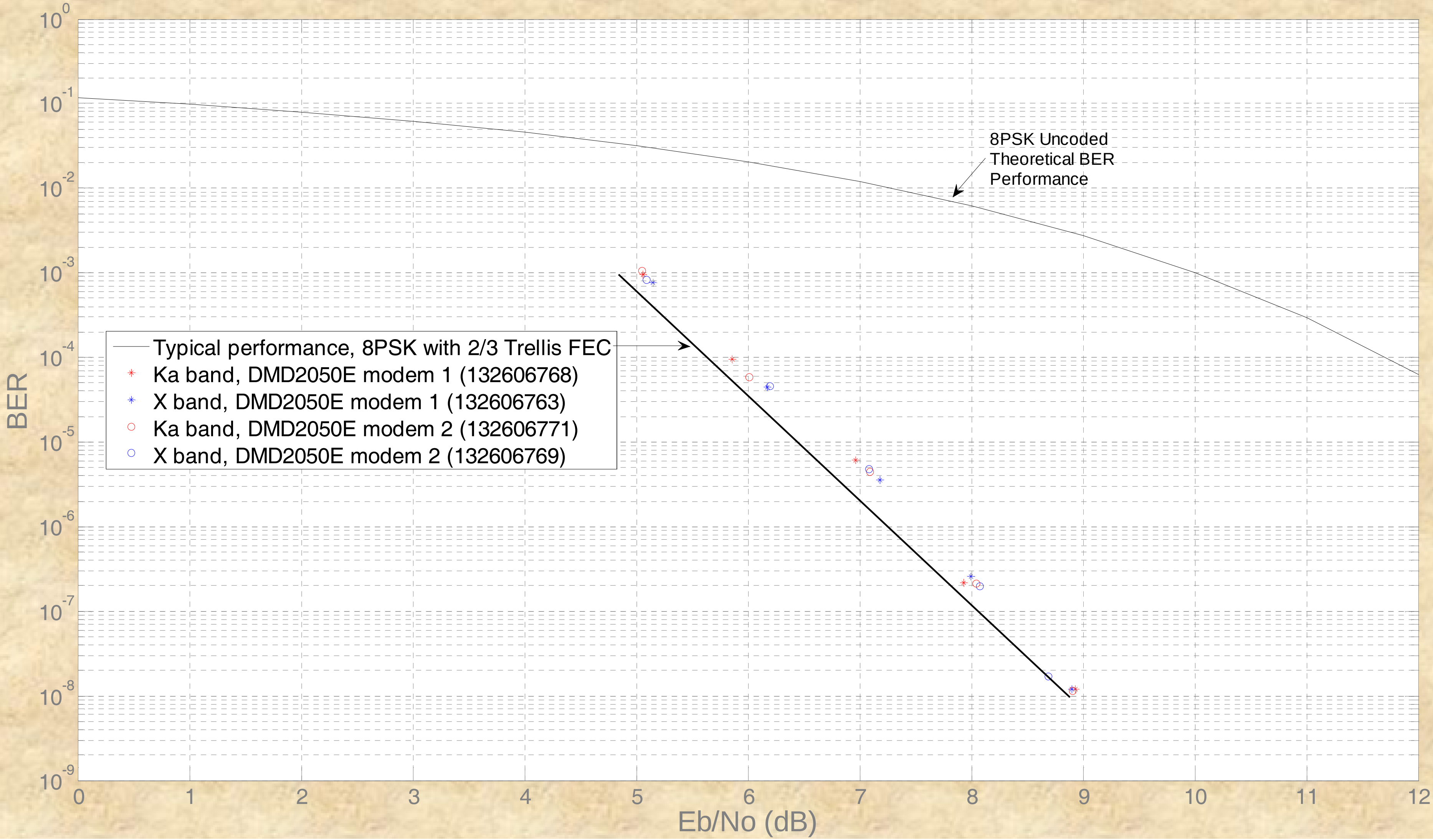
$N = 4.61/10^{-9}$ = 4.6 billion bits required.



QPSK with Turbo Product Code, Rate ½ Forward Error Correction (FEC) algorithm

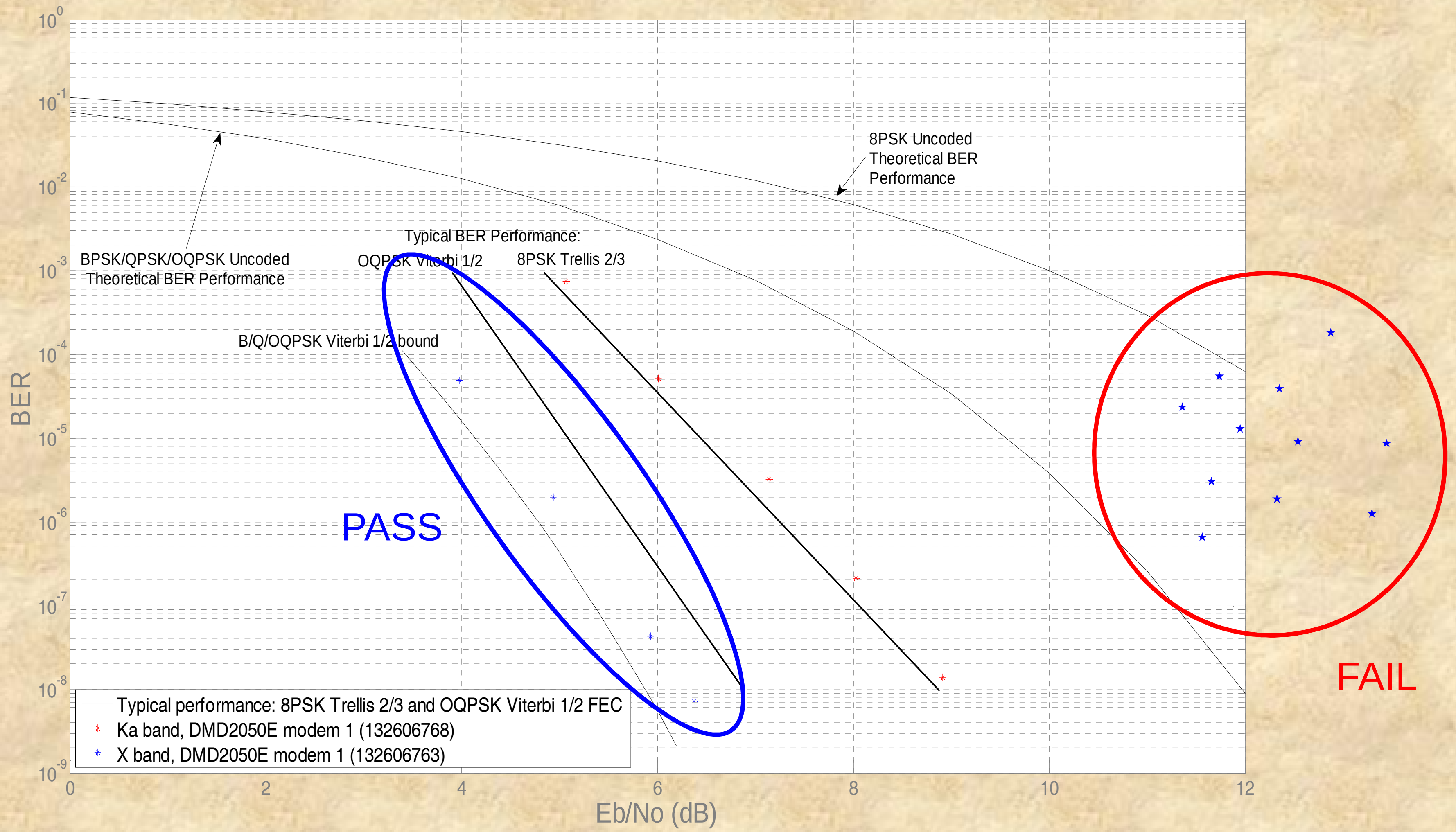
DKET FAT BER results

- The Rockwell-Collins DKET fixed land terminal passed the FAT BER test in both X and Ka bands, but the system was tested without the antennas.



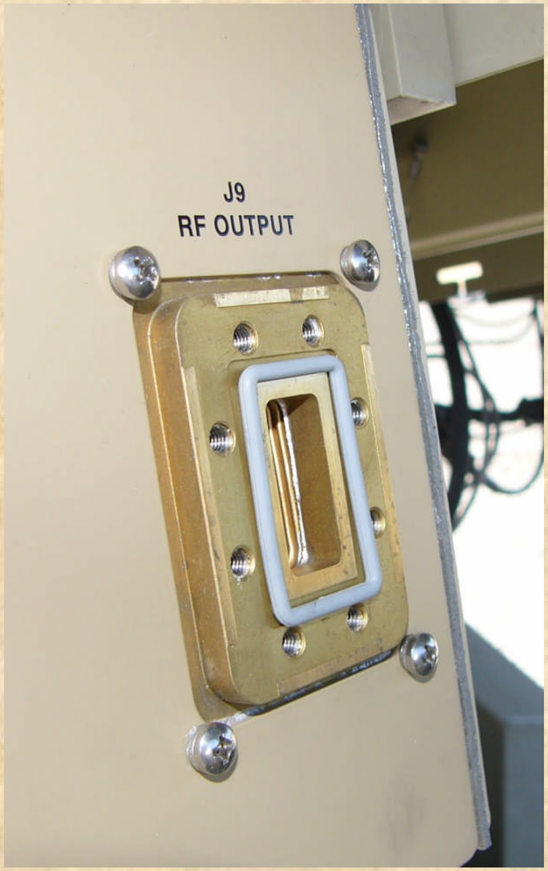
DKET ISAT BER results

➢ The Rockwell-Collins DKET fixed land terminal (arrived in NZ mid March 2014) passed the FAT BER test in both X and Ka bands, but initially failed the ISAT BER test in X band (as well as the EIRP and the PIM tests):

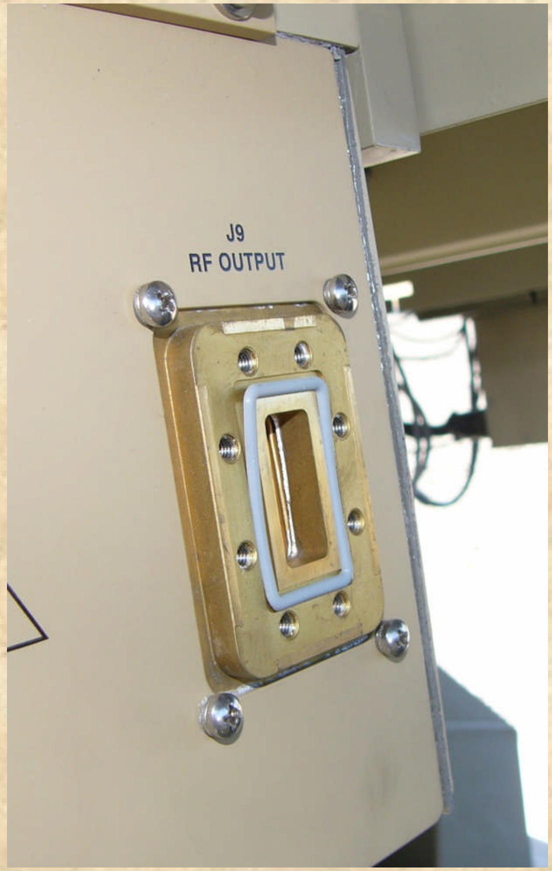


DKET FAT and ISAT BER results …

- CAUSE: The incorrectly installed gaskets were found at the joints of the rectangular waveguides in X band.



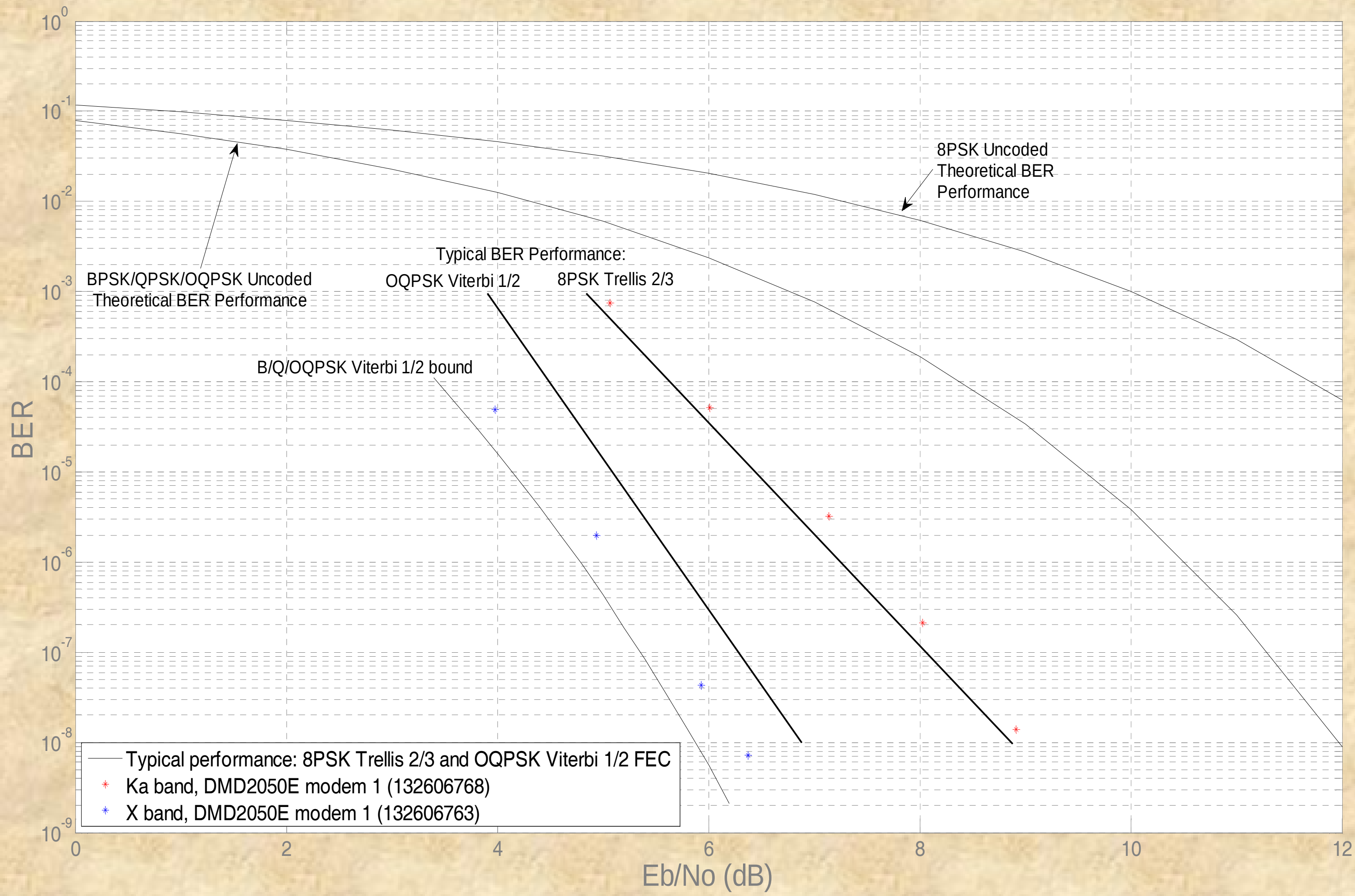
INCORRECT



CORRECT

… DKET FAT and ISAT BER results …

- The gaskets were replaced and the RC DKET passed the ISAT BER in X band.



DKET ISAT overnight BER results

- To further test the system in X band, a high Eb/No of 8.1 dB was used overnight.

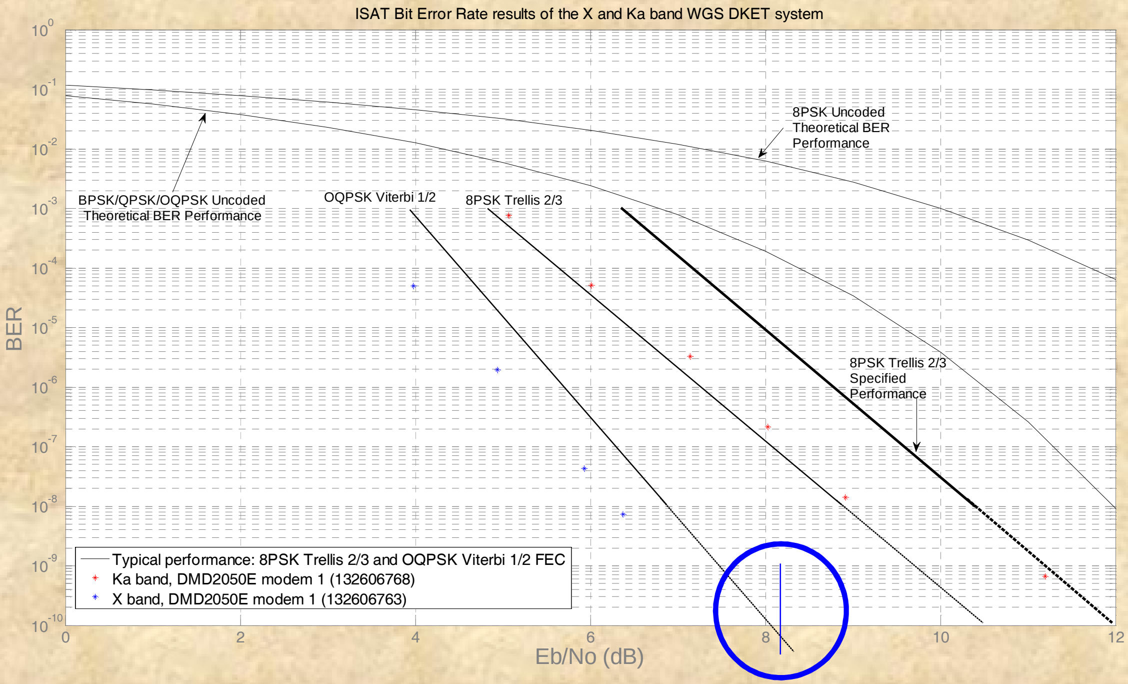
$$N = \frac{1}{BER}[-\ln(1 - CL)]$$

N x *BER* values

Errors	CL = 90%	CL = 95%	CL = 99%	CL = 99.999%
0	2.3	3	4.61	11.51

- *N* = 119.5008 billion bits were processed with 0 errors at the Eb/No = 8.1 dB in X band

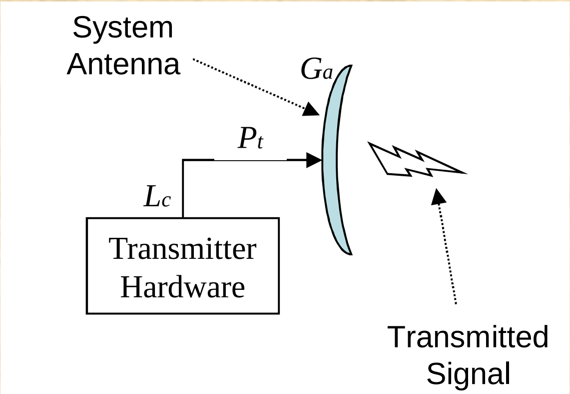
- It can thus be stated that at Eb/No = 8.1 dB we are 99.999% confident that the actual system BER is below 10^{-10} as:



N x *BER* = 11.51
N = 11.51/ 10^{-10} = 115.13 billion bits required for a 99.999% confidence level.

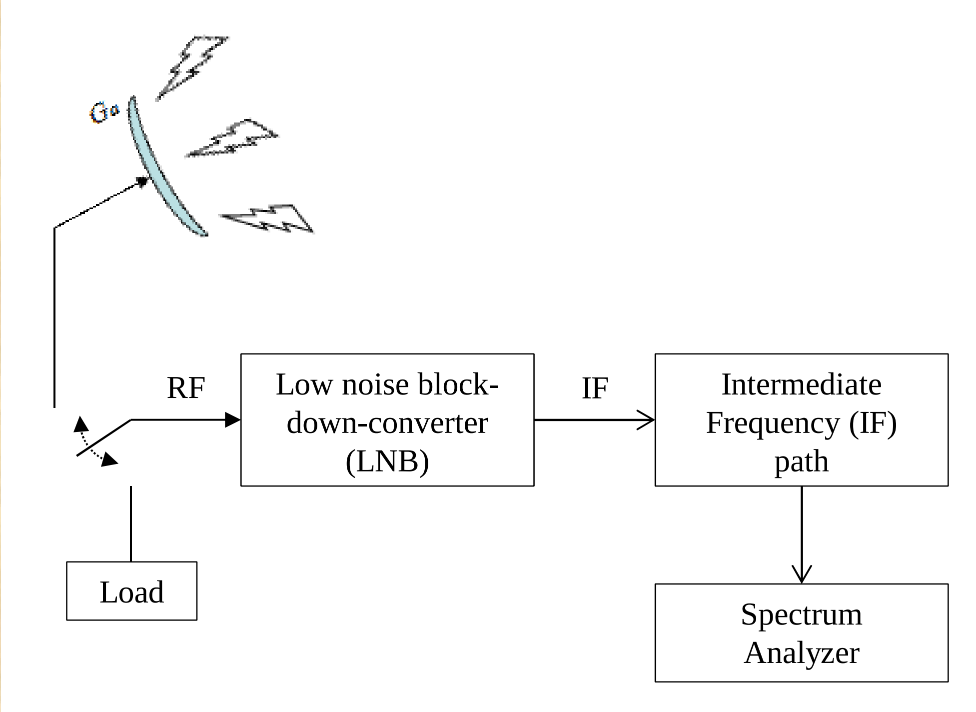
EIRP and G/T ratio

EIRP



$$P_{EIRP} = P_t - L_c + G_a$$

G/T using the Y factor method



$$Y = \frac{P_H}{P_C} \qquad T_S = \frac{T_{Load} + T_{LNA}}{Y} \qquad (G/T) = \frac{G_a}{T_S}$$

$$(G/T)\ \text{dB} = 10\log(G_a) - 10\log(T_S)$$

Maritime WGS terminals

- The RFT for WGS maritime completed

- The plan is to install maritime WGS capability on the:
  - ✓ Multirole vessel (Canterbury),
  - ✓ The frigates (Te Mana, Te Kaha)
  - ✓ The Offshore Patrol Vessels (Wellington, Otago)

- Easiest to install on the transport ship, hardest on the frigates (space limitations)

- No, or little operating constraints in international waters (band licencing)