AN ARTIFICIAL RADIO SIGNAL FOR VLBI SATELLITE TRACKING

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INTRODUCTION

Why observe a satellite with VLBI?

- ICRF is realized through VLBI observations of quasars [1].
- ITRF is the result of a combination of VLBI and satellite observations: SLR, GNSS, and DORIS [2].
- VLBI observations of Earth satellites can **improve the frame-ties between the ICRF and ITRF** [3], as illustrated in Figs 1 and 2.

Problem

- Currently there is no satellite emitting a suitable radio signal for VLBI.

Here we present

- **Preliminary concept for generation a broad-band noise-signal**.

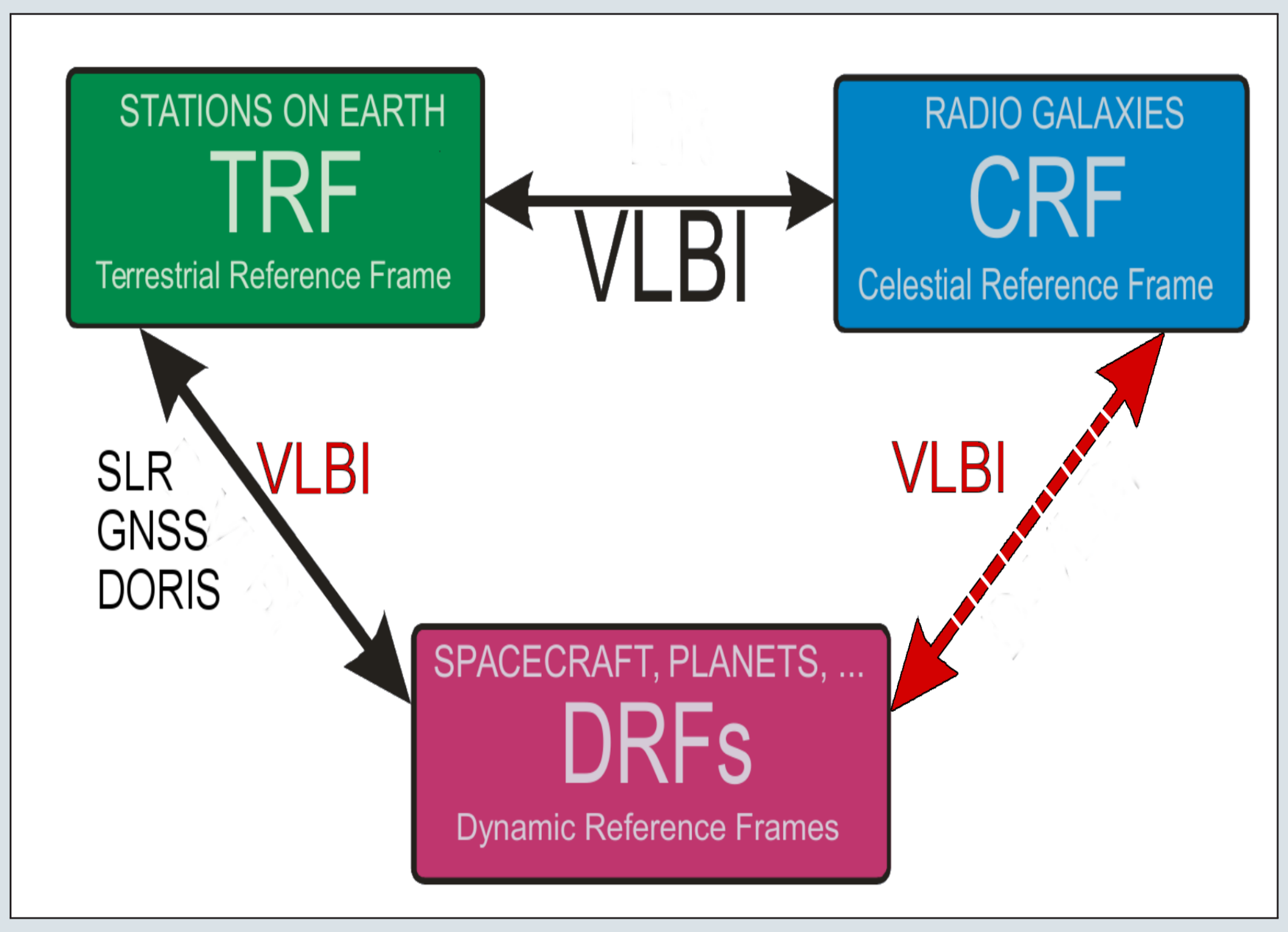

Figure 1: VLBI observations of Earth satellites fill the missing direct link between the celestian reference frame and the dynamic reference frames of satellites. Figure from [4].

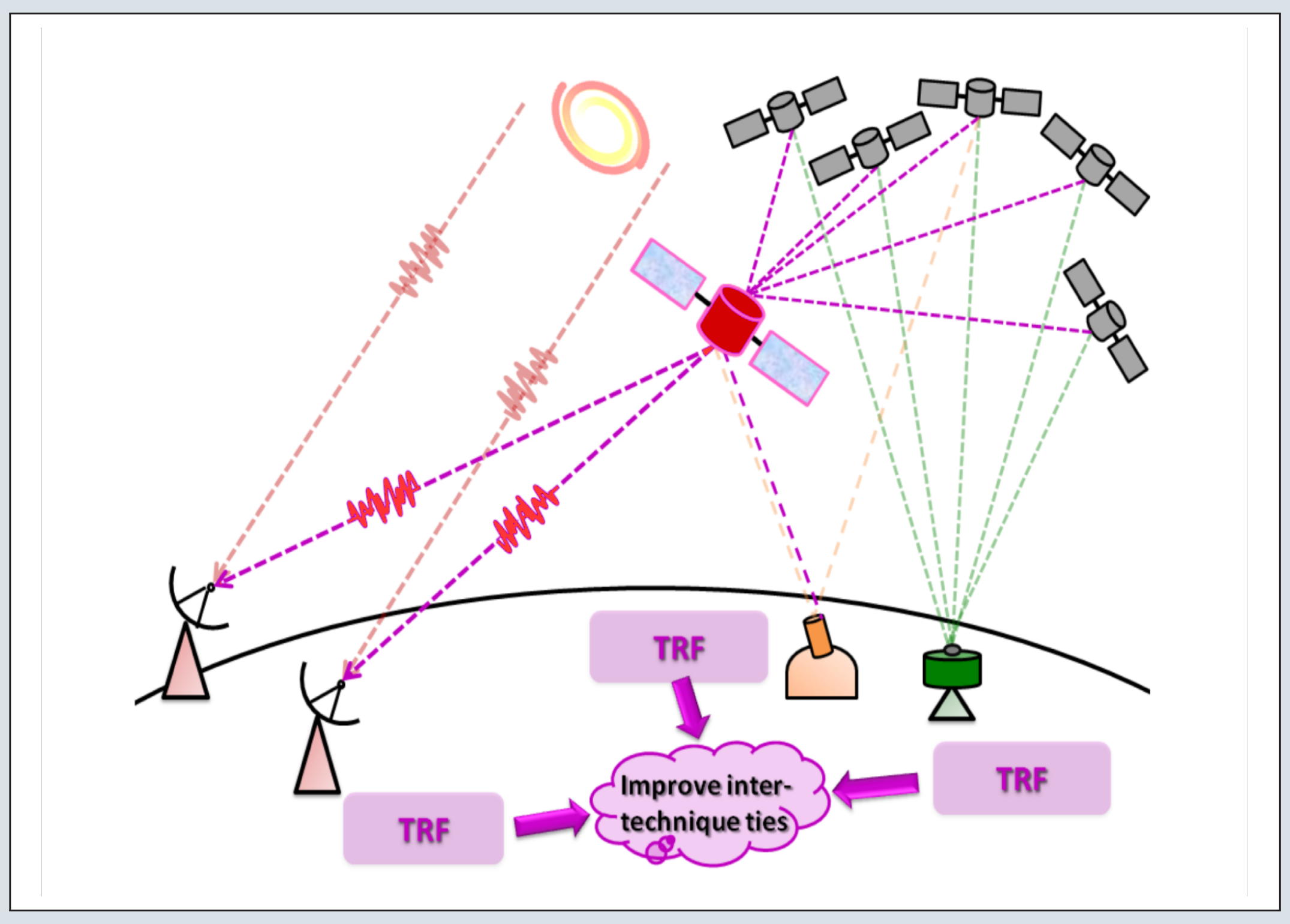

Figure 2: A satellite is tracked simultaneously by different space-geodetic techniques realizing a platform for co-location in space. Figure taken from [3].

RADIATION CONSIDERATIONS

To transmit an observable radiation by an antenna from a satellite, the transmitted radiation should be similar to that of a quasar in terms of **spectrum** and **intensity**:

- The spectrum has to be **flat** (ideal case).
- Covering a frequency range from **2 GHz to 14 GHz** (suitable for both legacy S/X observations and upcoming VGOS).
- The intensity should be similar to that of a typical quasar , i.e., ~**1-10 Jy**, to avoid any change in the attenuation level at the telescopes.

The link budget is the total of gains and losses of the radiation intensity from the transmitter to the receiver, which consist mainly of the antenna gain and path losses (free path loss and atmospheric attenuation, see Fig. 3).

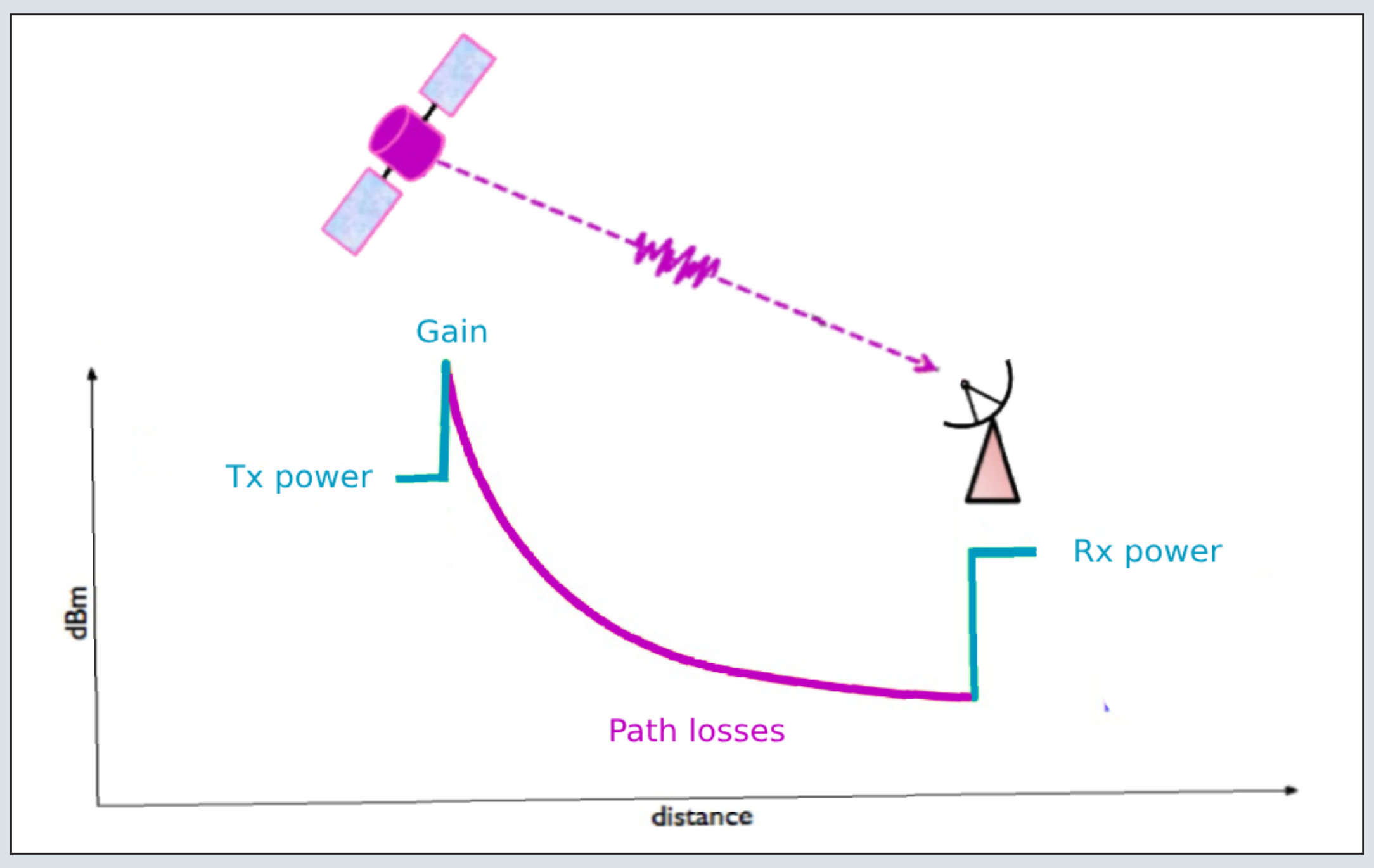

Figure 3: Link budget

Transmitted radiation + antenna gain = Received radiation - Receiving antenna gain + Path losses.

LINK BUDGET

The back wards computations of the transmitted signal have the following inputs:

- The radiation intensity of the received signal is 1 Jy.
- Satellite at 20 000 km altitude.
- The minimal elevation angle of the radio telescope is 5°.
- The antenna diameter is 13 m (VGOS standard).

Received radiation intensity =
$1\,\mathrm{Jy} = 10^{-26}\,\mathrm{W\,Hz^{-1}\,m^{-2}} = -260\,\mathrm{dBW\,Hz^{-1}\,m^{-2}}$

The **antenna gain** is shown in Fig. 4 regadding the formula $10\log_{10} k(\frac{D\pi}{\lambda})$, where D is the diameter of the antenna, k is the efficiency of the antenna and λ is the wavelengh of the received signal.

Path losses consist mainly of free path loss and atmospheric attenuation. Free path loss = $20\log_{10}\left(\frac{4\pi d}{\lambda}\right)$, where d is the distance between the transmitter and the receiver. The satelltite height is 20000 km, thus, the maximmum distance is 26370 km.

Atmospheric attenuations are estimated according to the ITU recommendations [6]. With assuming that the total path length between antenna and efective height of the atmosphere is 5 km in zenith direction, which will be 57 km at elevation up to $\epsilon = 5°$, and with standard atmospheric conditions, surface pressure at sea level of 1013 hPa and humidity of 7.5 g/m^3. Fig. 5 shows the attenuation due to dry and wet part of the atmosphere.

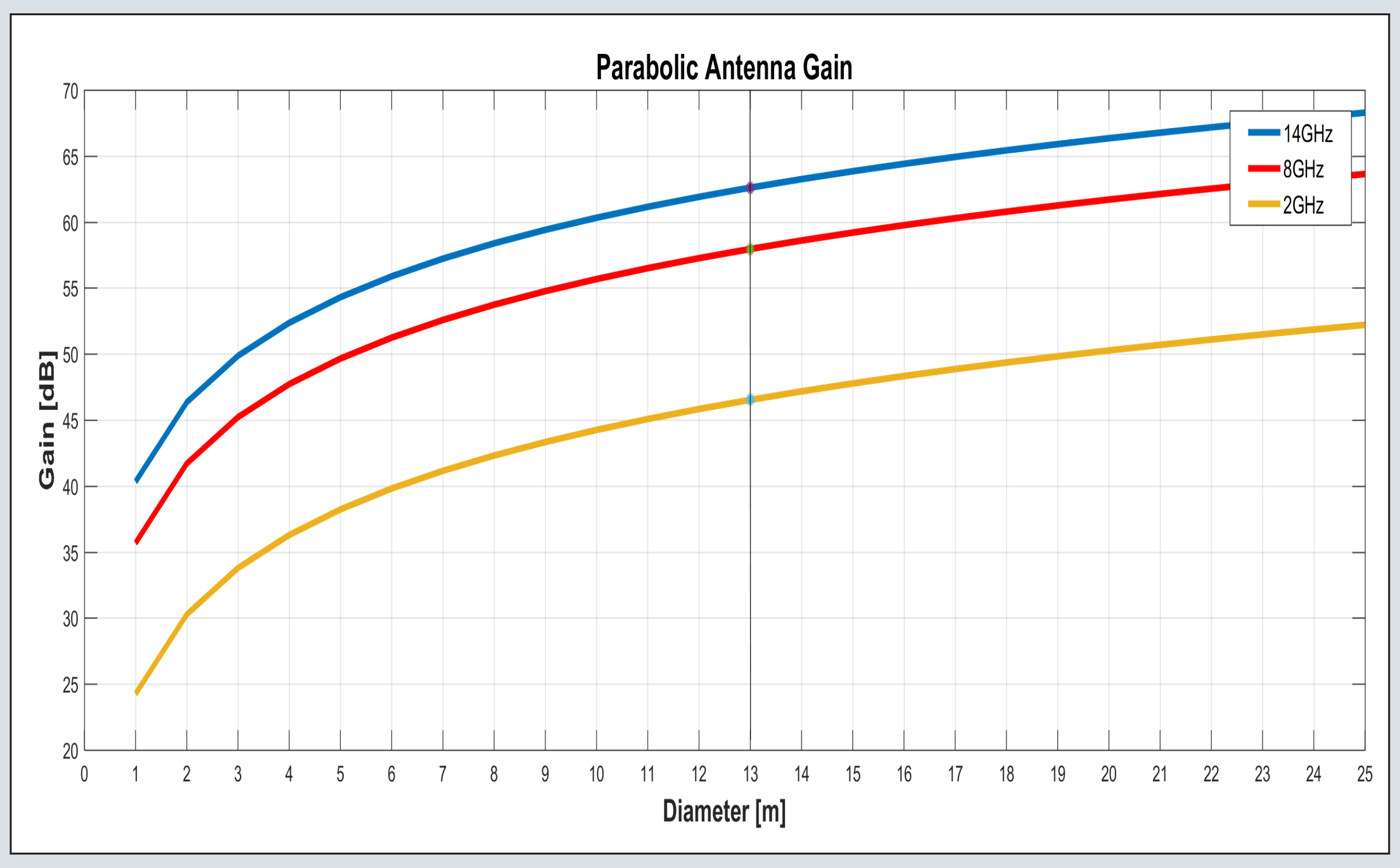

Figure 4: Parabolic dish antenna gain.

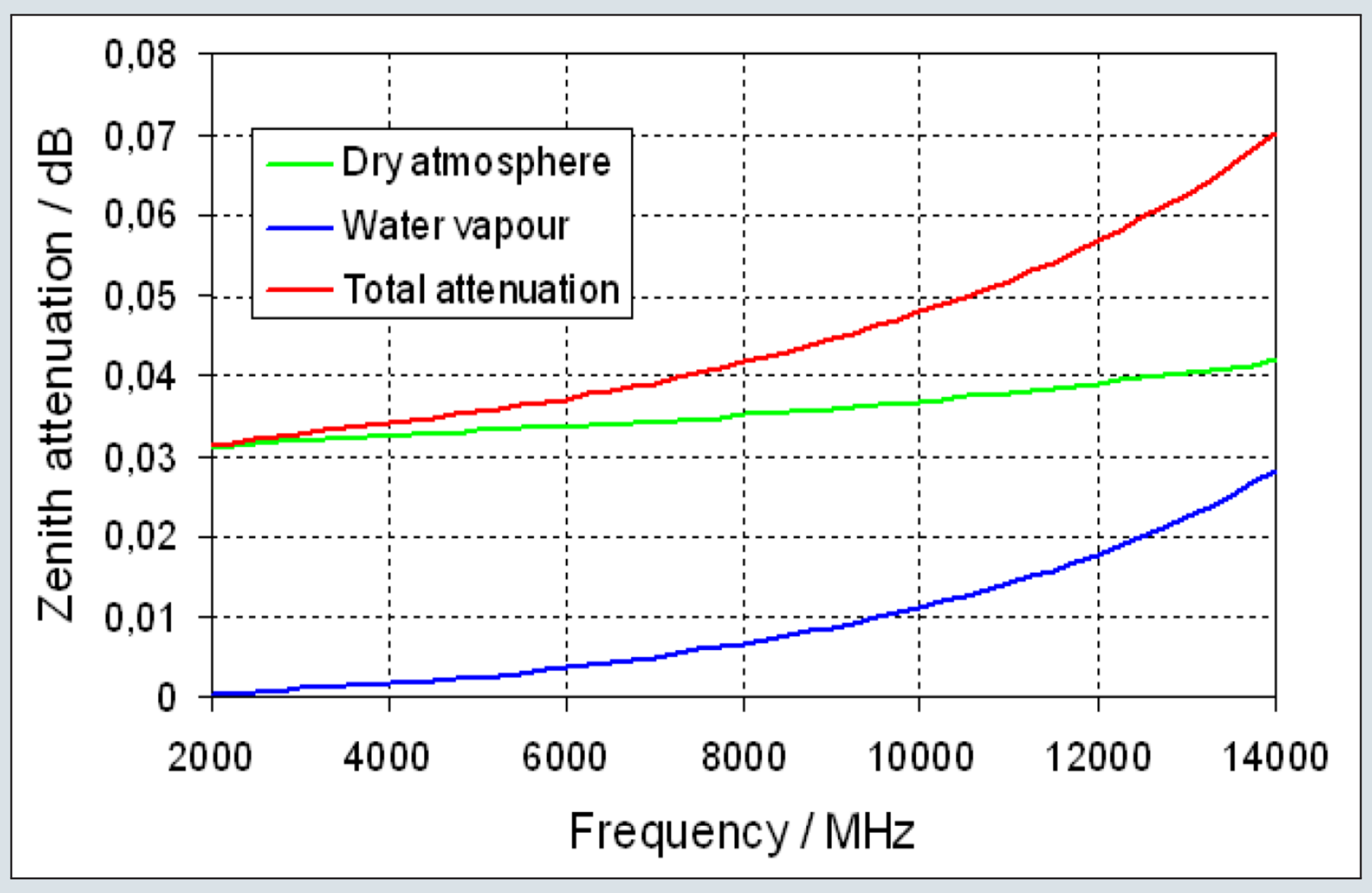

Figure 5: Atmospheric attenuation per kilometer.

INSTRUMENTS

The signal will be generated by a **noise diode**. The intensity of noise diode radiation is defined by the ENR (Excess Noise Ratio), which shows how much the noise source is above thermal noise in its power. The intensity can be approximated by adding the ENR to typical thermal noise level of -204 dBW/Hz.

The typical ENR of a noise diode is between 25 and 40. Thus, an **amplifier** is needed to generate a signal with the required intensity (see Table 1).

Since the bandwidth of the generated signal is wide i.e. ~ 12 GHz, a special kind of antenna need to be used to avoid any changes in the **phase center**, polarization and radiation pattern. A **log-spiral antenna** may best serve these purposes (see Fig. 6).

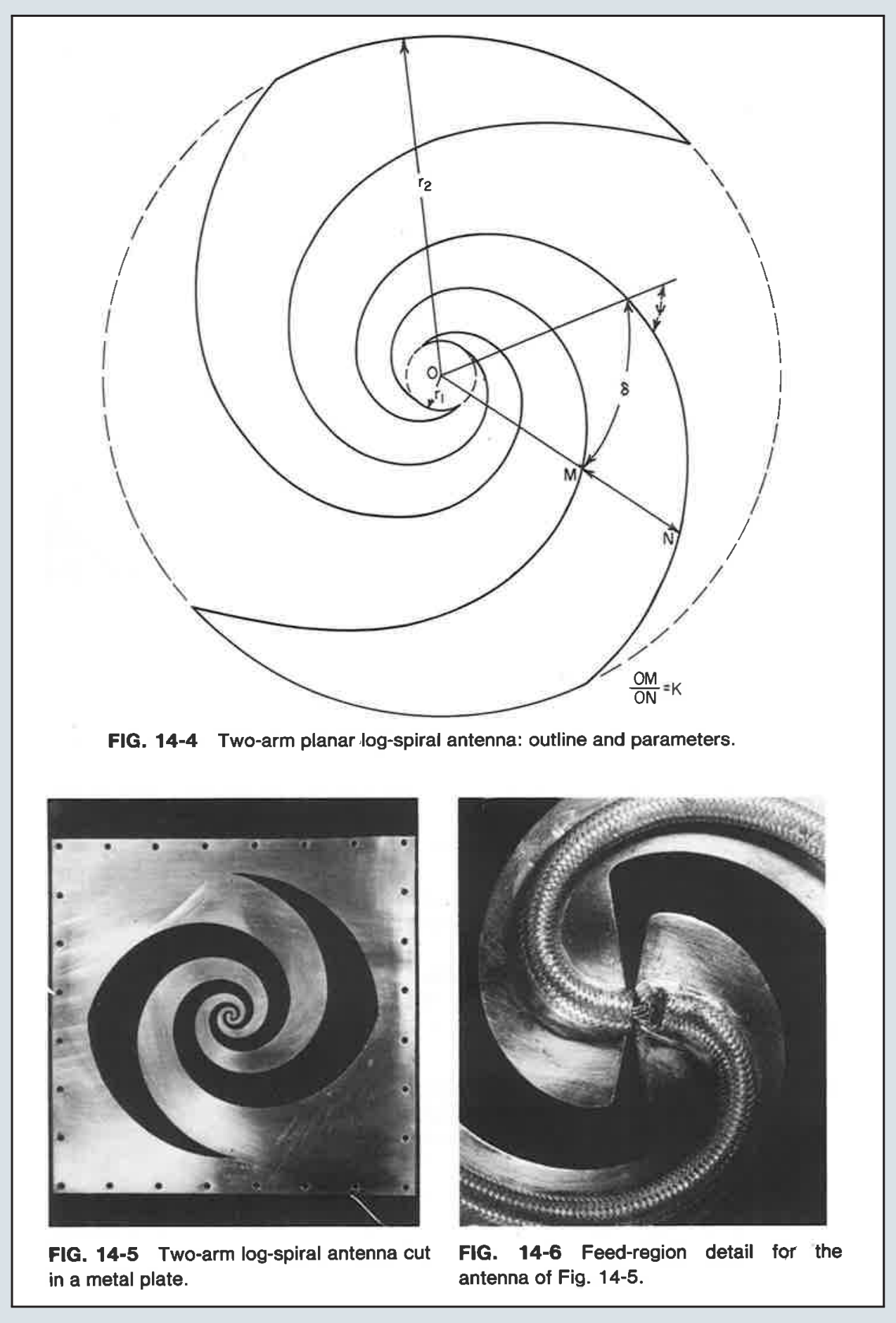

FIG. 14-4 Two-arm planar log-spiral antenna: outline and parameters.

FIG. 14-5 Two-arm log-spiral antenna cut in a metal plate.

FIG. 14-6 Feed-region detail for the antenna of Fig. 14-5.

Figure 6: Log-spiral antenna [5]

RESULTS

These are the results of our computations.

	Frequency		
Gain-Loss	2 GHz	8 GHz	14 GHz
Received intensity dBW Hz^{-1} m^{-2}	-260 dBW		
Free path loss at $\epsilon = 5°$ dBW	188	200	204
Atmospheric attenuation at $\epsilon = 5°$, dBW	0.5	0.5	1.5
Antenna gain dBW	- 46.5	- 58	- 63
Total transmitted intensity dBW Hz^{-1} m^{-2}	-118	-117.5	-117.5

Table 1: Results

CONCLUSIONS

The calculations presented here show that an artificial noise signal can be generated at the required intensity. This makes it an interesting option to add to, e.g., a **GNSS satellite**, thus implementing **co-location in space**. Further investigation of the possible emitted spectrum of the generated signal is needed in order to find the optimal solution for the entire analysis chain from correlation to final parameter estimation.

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